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Volume 152

ICES Herring Tagging Experiments in 1957 and 1958

En Commission chez
ANDR. FRED. HØST & FILS
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By

Olav Aasen K. P. Andersen J. Gulland
K. Popp Madsen D. Sahrhage

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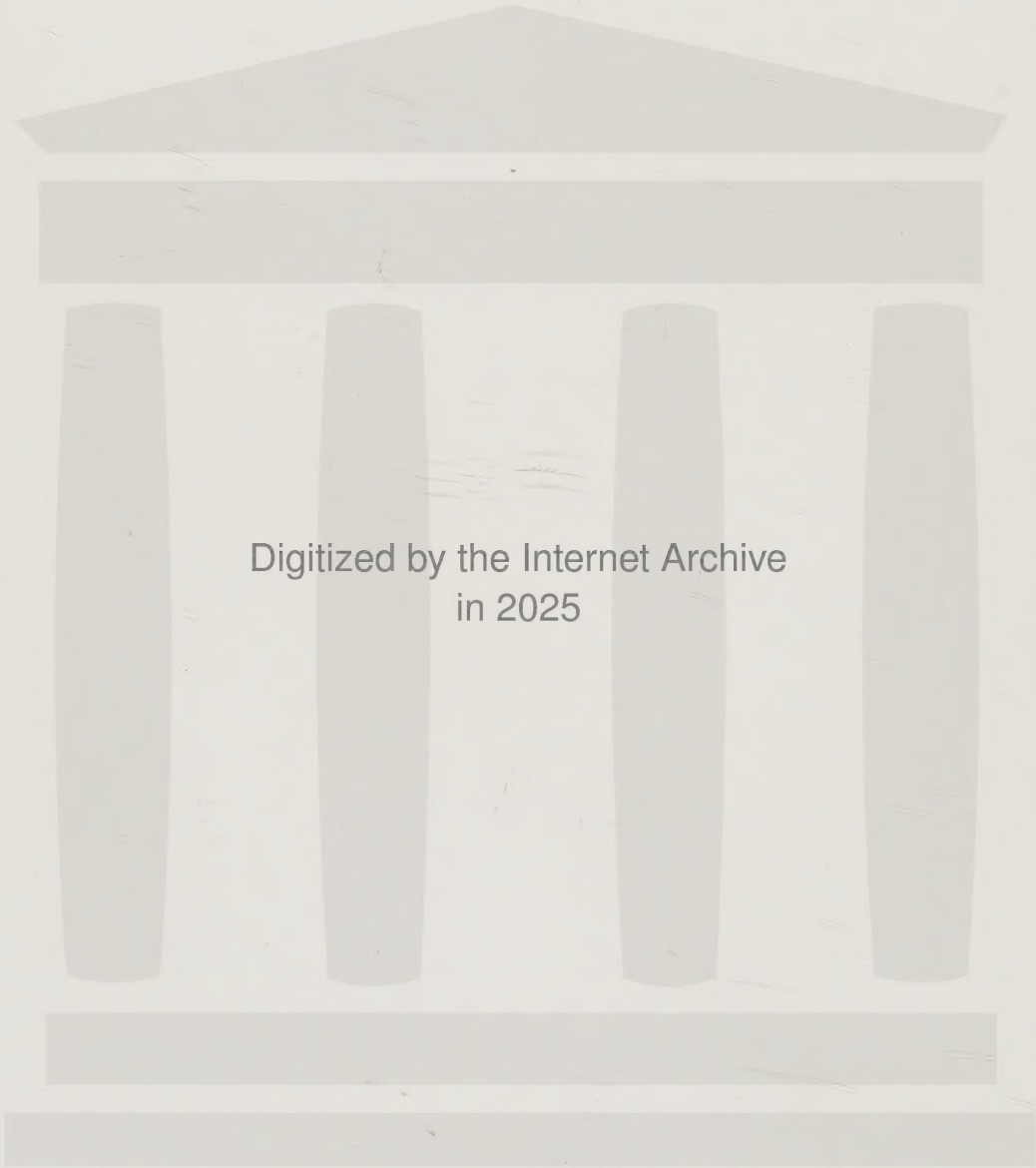

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I. Preface

It is a pleasure for the Council to present this report on herring tagging experiments in the North Sea in 1957 and 1958. The successful completion of the task is due to the willingness of a number of countries to co-operate and the competence of a large group of experts who have contributed in one way or another.

The plan was supported by the following member countries of the Council: – Denmark, the Federal Republic of Western Germany, the Netherlands, Poland, Sweden, the United Kingdom, and the U.S.S.R. Each of these countries contributed 20,000 Danish kroner to the tagging scheme of 1957, and they made it possible to continue the plan in 1958 by an additional grant of 10,000 kroner. Each of these countries has, therefore, allocated 30,000 kroner altogether. Besides this, Norway has supported the plan by placing gear, tags, and scientific equipment at free disposal and she did not charge the Council for the invaluable services of Mr. *Olav Aasen*, who acted as scientist-in-charge throughout the whole period of experiment. Without his skill and experience the plan would have been much more difficult to carry out.

I am pleased to extend my thanks to all the scientists who have been engaged in the tagging scheme and special thanks must be paid to those who have spent their effort in compiling one or more of the preliminary reports which have been distributed to all instances concerned. Besides the members of the Editorial Committee, being responsible for the present final report, the names of *Erik Bertelsen*, *David Cushing*, *Gerhard Krefft*, and *Hans Höglund* should be mentioned.

Reference must be made to the "History of the Project" in this report and special tribute should be paid to those countries which have placed research vessels at disposal, as mentioned in the report.

It is hoped that the good experience, which has been gained through this international co-operation within the frame of ICES, may encourage similar undertakings in the future when urgent solutions of vital questions are required.

Finally, it should be noted that this report deals only with the internal taggings in 1957 and 1958 and the results obtained through them, and furthermore only for recaptures during the autumn season in the year of tagging. The working up of the data from the external taggings will have to be left until a later date.

Árni Friðriksson

II. Introduction

The so-called "Industrial Fishery" for immature herring on the Bløden Ground began in July 1950[1]) when a Danish cutter accidentally found dense concentrations of young herring 60—100 nautical miles west of Esbjerg (Ref. 9). Since that time this fishery has developed greatly in Denmark and in the German Federal Republic (Table 1).

The herring are caught by pair trawlers and single ship trawlers and are utilized almost exclusively for processing in reduction plants. Typically, there are two fishing seasons: the spring fishery (January/beginning of May) and the autumn fishery (July/October). The fish belong mainly to the I- and II-group herring with average lengths of about 15 and 20 cm in spring, while in the autumn the corresponding figures are 19 and 22 cm. 0-group and III-group herring are caught occasionally. The catches usually include a small amount of whiting and other species. The "Bløden herring" is further characterized by having a mean vertebral number of about 56·57, while the average number of keel scales is 14·79 (Ref. 15). Further information on the fishing and composition of the catch is given in Refs. 7, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, and 21.

As a general rule, according to Bertelsen and Popp Madsen (Ref. 7), the herring tend to aggregate in the autumn in the boundary region between water masses of different temperatures, and hence the area of the "Bløden" fishery may be roughly defined as the ground east and north-east of the Dogger Bank covered by bottom water of low temperature.

This rapidly expanding fishery for small herring did not fail to attract the attention of the fisheries authorities and of the herring biologists in the various countries participating in the herring fisheries of the North Sea. The crucial question was:—

> To what extent did the "Bløden" fishery for small herring affect the North Sea herring fisheries as a whole?

When the East Anglian herring fisheries changed character in the 1951 season (Ref. 8), one school of thought maintained that one of the prime causes for the change and also the subsequent failure in 1955 was the new industrial fishery for immature herring. The material at hand, however, failed to yield evidence which convinced the scientists working in the North Sea.

[1]) A Danish fishery for 0-group herring had been in progress since 1948.

Table 1

Danish and German landings (in thousands of tons) of herring in spring and autumn for the period 1950–1959

	Year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
Danish	Spring	0·5	4·8	6·6	6·2	11·0	8·2	19·6	19·5	30·7	24·3	131·4
	Autumn	4·9	26·7	25·4	42·9	44·8	51·9	57·2	58·7	93·0	84·6	490·1
German	Spring	–	–	–	–	–	–	–	–	–	–	–
	Autumn	–	7·2	13·7	25·3	38·4	48·0	24·2	17·1	25·8	40·5	240·2
Total	Danish	5·4	31·5	32·0	49·1	55·8	60·1	76·8	78·2	123·7	108·9	621·5
	German	–	7·2	13·7	25·3	38·4	48·0	24·2	17·1	25·8	40·5	240·2
Total	Spring	0·5	4·8	6·6	6·2	11·0	8·2	19·6	19·5	30·7	24·3	131·4
	Autumn	4·9	33·9	39·1	68·2	83·2	99·9	81·4	75·8	118·8	125·1	730·3
Grand	Total	5·4	38·7	45·7	74·4	94·2	108·1	101·0	95·3	149·5	149·4	861·7

III. History of the Project

In 1956 a special scientific meeting was called to discuss the disturbing changes that had recently taken place in the herring fisheries of the southern North Sea (Ref. 2.). The meeting agreed in a resolution "... to urge all interested countries to participate in a co-ordinated programme..." including "... an intensive tagging programme".

The Herring Committee considered this proposal and appointed an *ad hoc* Committee to draft a general programme of tagging work. The *ad hoc* Committee submitted a draft (Ref. 1) which was agreed upon by the Herring Committee and passed with a recommendation to the Council (loc. cit.) and subsequently approved (loc. cit., pp. 15—16).

Acting on this decision a group of three nominated experts met in Copenhagen in November 1956 and made a detailed plan of work for the Bløden Ground taggings with an estimate of expenses. On the strength of this, the Secretary General of ICES approached the various governments and seven countries agreed to participate in the scheme.

With the financial support thus secured, the Secretary General in due course convened a meeting of representatives from the participating countries. At this meeting, which took place in Copenhagen in February 1957, the final administrative decisions were made.

The details of the further preparations were now placed in the hands of appointed bodies of experts who carried the scheme through with notable success. At the ICES meeting in the autumn of 1957, the Herring Committee considered the work done and recommended that the tagging programme of 1957 should be continued in 1958 and that funds be made available for working up the results (Ref. 3). These recommendations were approved by the Council (loc. cit., p. 23).

In December 1957, three experts met in Copenhagen to prepare a preliminary report on the results of the experiments. Copies of this report were circulated to the participating countries by the Secretary General and requests were sent to the various governments for continued financial support for the tagging work. The response was positive: all the earlier participants approved.

In February 1958, two experts and the Secretary General met in Lysekil to discuss the further work. It was agreed in general to adhere to the 1957 plan and that the same experts (with certain amendments) should be entrusted with the execution of the experiment, which was subsequently carried out successfully.

At the next meeting of ICES in the autumn 1958, the Herring Committee again considered the taggings. The general feeling was that a continuation of the work was not called for at present, but that the work should be continued in the future as requirements demanded (Ref. 4). The Committee recommended further that funds be provided to evaluate the collected material. The Council approved of the Herring Committee's recommendation and this decision brought to a close the first phase of the ICES herring tagging experiments on the Bløden Ground.

In May 1959 a group of four experts met in Copenhagen and prepared a preliminary report on the results from the 1958 experiment. Copies of this report were circulated to the participating countries. The whole tagging scheme was reconsidered at the next meeting of ICES in October 1959, and the Herring Committee recommended that a draft for a final report should be prepared for the following meeting and that funds be made available for this work (Ref. 5). The Council agreed to this procedure (loc. cit., p. 43) and the authors were requested to meet in Copenhagen in May 1960 to prepare it. The contents of the present paper is the result of the work of this group, which is mainly based on the five preliminary reports presented to the Herring Committee at the various stages of the project, by varying groups of experts. The names of the scientists participating in the field work are given in Appendix 2.

IV. Tag Liberations

1957 experiment

In the plan of work drawn up by the expert meeting at Copenhagen in November 1956 (page 6) it was recommended that:— "It would be most welcome if national research programmes covered additional work in the area". This recommendation was seconded by the meeting of Delegates (Appendix 1) and consequently the participating countries were approached by the naturalist-in-charge asking if research ships could be expected to work in the Bløden Ground area during the tagging experiments. Denmark and the United Kingdom replied in the affirmative, and this provided an opportunity to carry out a pre-tagging survey of bottom temperatures and fish distribution. The survey was carried out by R/S "Jens Væver" from 16.—24. July in the northern half, and by R/V "Platessa" from 18.—23. July in the southern half of the area. The dividing line was latitude 55°15′N. The combined results were charted and used as a basis for planning the first stages of the tagging work (Figure 1).

Tags were released from four ships:—

1. The chartered purse-seiner M/S "Rygrunn" from Norway; 24. July to 19. August.

As the herring only left the bottom at night, it was found necessary to concentrate the dispersed shoals with the use of strong searchlights. On 8 nights only were the weather and tidal conditions suitable for fishing, and, in all, 5 shots were made, 3 of which provided herring of suitable size for tagging. On the other two occasions only 0-group herring was caught.

2. The research ship R/S "Jens Væver" from Denmark; 16. July to 14. August.

After the pre-tagging survey was completed this ship was primarily used as a scout ship, her job being to locate and identify echo-traces in the north-eastern part of the area.

3. The research ship R/S "Sir Lancelot" from England; 10. to 26. August.

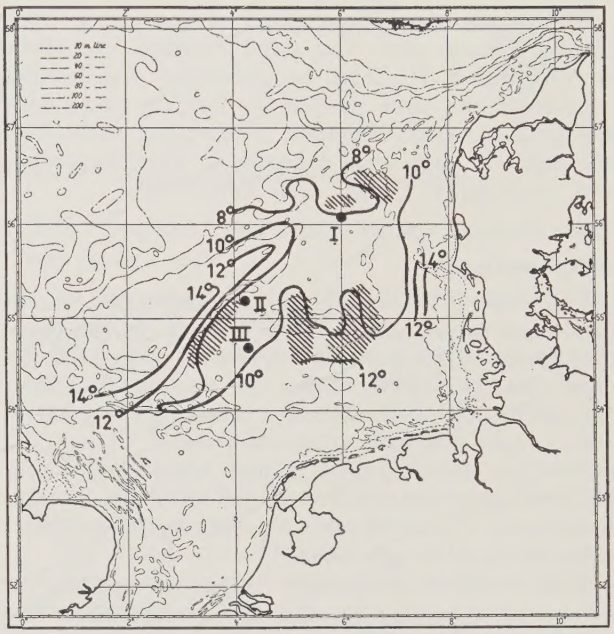


Figure 1. Pre-tagging survey in 1957. Bottom temperatures in °C. Hatched areas: echo-traces. Roman numerals: position of liberations.

This ship was used to survey the southern half of the area, locating and identifying echo-traces. After M/S "Rygrunn" left the Bløden Ground, internal and external tagging was carried out on trawl-caught fish.

4. The research ship R/S "Clupea" from Scotland; 7. to 27. August.

R/S "Clupea" was used to survey the north-western part of the area. After M/S "Rygrunn" left the Bløden Ground, internal and external tagging was carried out on trawl-caught fish.

A grand total of 14,519 tagged herring were released in 28 different liberations. The total number

Table 2
Tags released 1957

Tag type[1]	I		L		D	H	S		
Ships Gear[2]	P	T	P	T	P	P	N	T	Total
M/S "Rygrunn"	9,930	–	–	–	–	–	–	–	9,930
R/S "Jens Væver"	–	50	51	–	74	–	–	–	175
R/S "Sir Lancelot"	–	1,739	12	177	–	379	–	–	2,307
R/S "Clupea"	–	592	–	119	–	–	96	1,300	2,107
Total	9,930	2,381	63	296	74	379	96	1,300	14,519

[1]) Types of tags: – (I) Internal; (L) Lea; (D) Danish Lea; (H) Hodgson; (S) Scottish combination.
[2]) Fishing gear: – (P) Purse-seine; (T) Trawl; (N) Drift-net.

of tags, external and internal, released from each ship, is shown in Table 2.

The details of positions, dates of liberations, types of tags, fishing gear, and serial numbers are given in Appendix 3. It should be mentioned that herring released at the same position and at the same date are given the same liberation number (for each ship) although the fish were released in smaller batches and, to a large extent, even individually.

1958 experiment

From the 1957 experiment two important conclusions were drawn which had a bearing on the planning of the 1958 experiment: firstly, the tagged herring only dispersed slowly from the tagging positions. Secondly, the total recovery percentage of purse-seine caught internally tagged fish was 3·5 % against 0·3 % for the internally tagged trawl-caught fish, i. e., the tagged purse-seine caught herring had a ten times better chance of surviving the tagging operation than the trawl-caught one.

This second circumstance ruled out tagging of trawl-caught herring for the 1958 experiment. The purse-seiner M/S "Rygrunn" was therefore again chartered for providing live herring, and during the experiments only purse-seine caught fish were used. More importance was placed on the pre-tagging survey, accompanied by experimental trawling to establish the size composition of the shoals and thus to avoid areas with fish unsuitable for tagging. The participating countries placed five research ships at the disposal of the survey work. The Bløden Ground was divided into four subareas allotted to the five participating vessels as shown below[1]):—

"Michael Siedlecki II" (Poland)	"Jens Væver" (Denmark) "Sir Lancelot" (England)
55°35′ N	
"Clupea" (Scotland) "Sir Lancelot" (England)	"Willem Beuckelsz" (Netherlands)
4°50′ E	

Survey lines were worked with echo-sounders, and hydrographic stations were made every 10 miles. Radio contact was established twice a day.

The distribution of bottom temperatures is shown in Figure 2. In the beginning of the week of survey, the temperatures in the north-eastern part of the area were rather below normal, the conditions being, however, very unstable. The survey was not favoured with good weather conditions and the wind force was 4—8. The turbulence caused by the wind was strong enough to mix the water column in the eastern part of the area, so by the end of the survey

[1]) Co-ordinator: the cruise leader on the Danish ship.

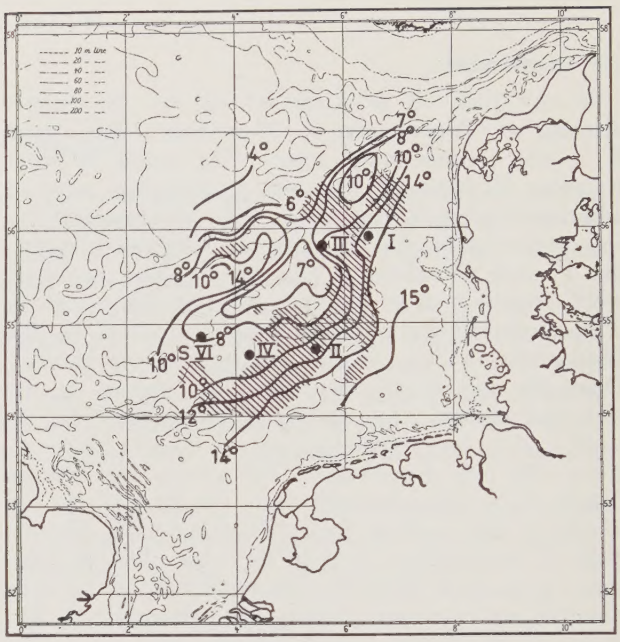


Figure 2. Pre-tagging survey in 1958. Bottom temperatures in °C. Hatched areas: echo-traces. Roman numerals: position of liberations.

the temperature conditions were about normal as compared with former years. The discontinuity layer present over most of the area was observed at 20—25 m depth.

The very good fishery during the spring of 1958 gave some reason to believe that the stock of young herring was bigger than in 1957. This was supported by the results of the pre-tagging survey. As shown in Figure 2, echo-traces were found over a very wide area. In general, the echo-traces were a little off the bottom so research vessel trawling was not entirely successful. This, however, is a well-known feature at the beginning of the herring season, especially when the bottom temperature undergoes rapid changes due to strong winds.

Following the pre-tagging survey the participating ships (except R/S "Clupea") met in Esbjerg, together with M/S "Rygrunn" and R/S "Skagerak" on the 4. August in order to prepare charts showing bottom temperatures and herring concentrations in the area for the tagging ships. These charts proved very useful in the first fortnight when there was little difficulty in finding the herring in the localities where they had been located (Figure 2).

Tags were released from three ships:—

1. The chartered purse-seiner M/S "Rygrunn"; 6. to 29. August.

Table 3
Tags released in 1958

Ships	Tag types[1]) I	L	D	B	Total
M/S "Rygrunn"	6,898	–	–	–	6,898
R/S "Skagerak"	999	3,300	100	62	4,461
R/S "Sir Lancelot"	–	1,220	–	–	1,220
Total	7,897	4,520	100	62	12,579

[1]) Types of tags: (I) Internal; (L) Lea; (D) Danish Lea; (B) Bolster. Fishing gear: purse-seine throughout.

As in the previous summer, fishing took place only at night and the shoals were concentrated by means of strong searchlights. The weather was much more favourable than in the preceding year (see Figure 4) and seven successful shots were made. Only internal tagging was carried out on this ship.

2. The research ship R/S "Skagerak" from Sweden; 6. to 29. August.

Since only purse-seine caught fish were used, R/S "Skagerak" scouted for herring alongside M/S "Rygrunn" between the taggings, and regular temperature measurements were taken. Batches of herring were transferred in keep nets from the seiner to R/S "Skagerak", on which mainly external tagging was carried out.

3. The research ship R/S "Sir Lancelot" from England; 6. to 12. August.

This ship was also used as a scout ship between the taggings, which were performed on herring transported in keep nets from M/S "Rygrunn". Only externally tagged fish were released.

12,579 tagged herring were released at seven different localities. In Table 3 the total number of tags released from each ship is shown.

The details of positions, dates of liberations, types of tags, fishing gear, and serial numbers are given in Appendix 4.

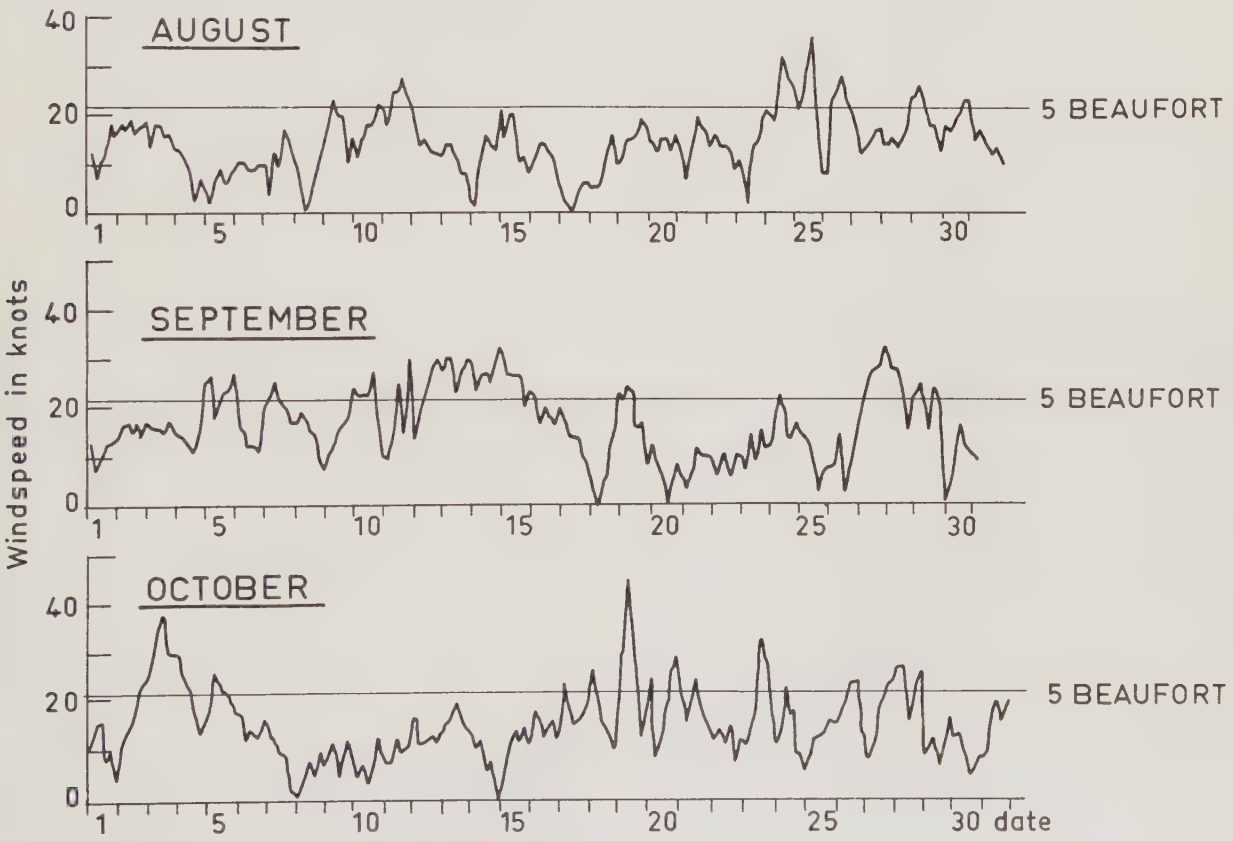


Figure 3. Daily windspeeds (in knots) at E. R. lightship (55°23′N–6°57′E) during the autumn fishing season of 1957.

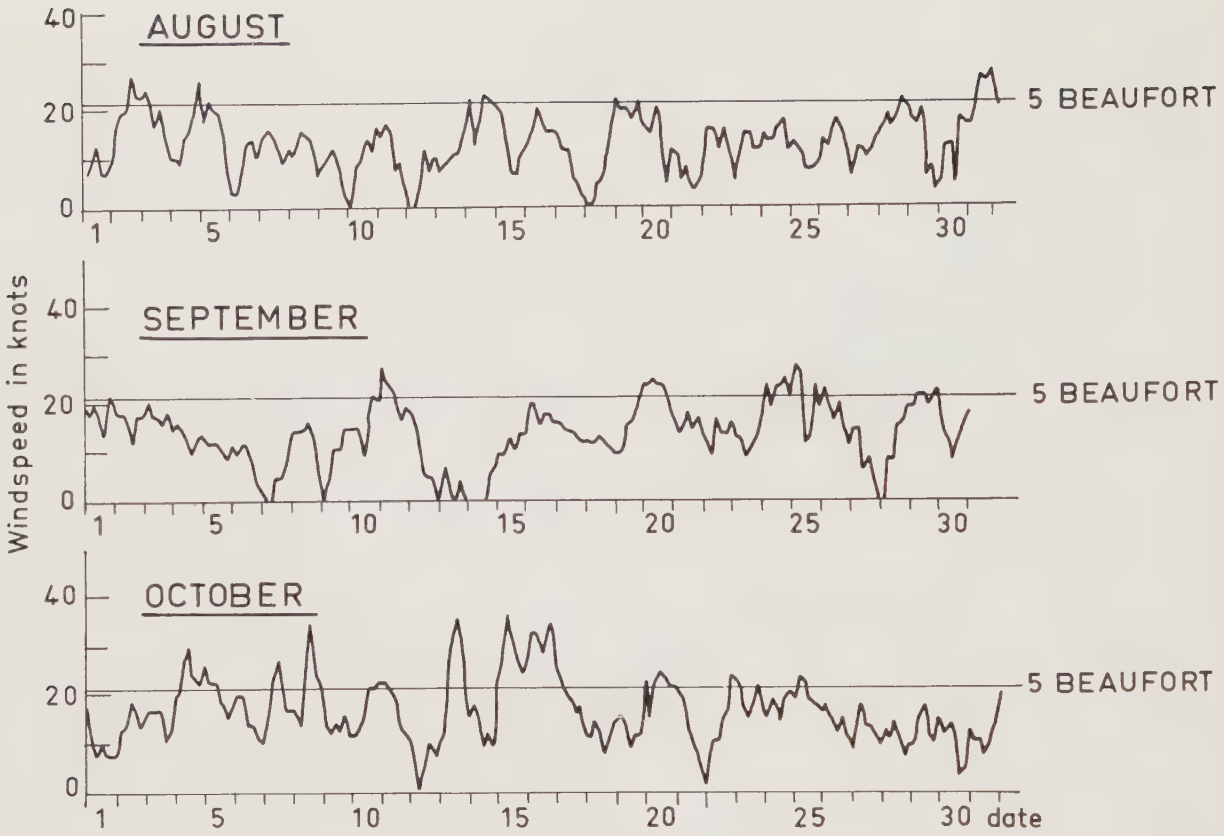


Figure 4. Daily windspeeds (in knots) at E. R. lightship (55° 23′N–6° 57′E) during the autumn fishing season of 1958.

V. Collection of Statistics

Bløden Ground 1957 and 1958

Danish catch and effort statistics

The collection in Denmark of detailed statistics of catch and effort in the industrial fishery in the North Sea was started in June 1957. The work was organized by the head of the Danish Fishery Statistical Department, Mr. S. N. Sørensen. The basic information on gear, position and numbers and average duration of hauls is obtained from the fishing skippers by fishery control officers at all main landing ports. Further details on size and composition of each landing can be found in the factory files. The information is compiled by the Statistical Department of the Danish Ministry of Fisheries on a punch card system, where all relevant data are summarized by landing port, gear, week, and statistical rectangle (about 15 × 15 nautical miles).

In the preliminary analysis of the tagging results it was found that only in Esbjerg had the number of returns reached a sufficiently high level to be of use in estimating the effect of the fishery upon the stock of young herring. Consequently, the following remarks on the further treatment of the catch and effort statistics refer especially to Esbjerg, but the methods described also apply to statistical material collected in other Danish ports.

Two problems arise in connection with the further treatment of the material:—

(i) The information (reported catches) only cover a part of the total catch due to the restricted amount of personnel available for this special task. It is, therefore, necessary to calculate *raising factors* week by week (because the proportion varies from week to week) to convert reported catch and effort to totals.

(ii) The Danish fishery is carried out by single boat and pair boat trawling, the latter being the more important. The fraction of the total catch covered by the reported catch is different for the two methods of fishing, and so the raising factors have to

be calculated separately. There is further a difference in fishing power between single and pair trawlers. As the unit of effort, one hour of pair trawling is chosen which requires a factor to convert the effort of single trawlers into that of pair trawlers.

The fraction, reported catch/total catch, is different for the two methods of fishing because no information on a single trawler will be obtained if the skipper is not interviewed, while only one of the two skippers from a pair trawling team needs to be interviewed to obtain information on both ships. Prior to July 1958 no information was available, concerning the total catch landed by single and pair trawlers, respectively. Consequently, it was not possible to calculate separate raising factors directly.

If, however, we assume that the skippers interviewed are chosen at random and the landing capacities of boats engaged in single and pair trawling are of the same order, then the following theoretical approach is possible:—

If the probability of getting an interview with a skipper from a single trawler is equal to the cover fraction (reported catch/total catch) of single trawlers, and the probability of getting information on a pair trawler team likewise is expressed by the cover fraction of pair trawlers, then

$$d_p = d_s\,(2 - d_s) \qquad (1)$$

where d_s = cover fraction of single trawlers,
d_p = cover fraction of pair trawlers.

Using the following notation:

C = total catch
c = total reported catch
s = reported catch of single trawlers
p = reported catch of pair trawlers
$d_c = \frac{c}{C}$ = fraction of total catch covered by total reported catch

we have

$$d_c = \frac{s+p}{\frac{s}{d_s}+\frac{p}{d_p}}$$

and by introducing (1)

$$d_s = \frac{s}{2\,C} + 1 - \sqrt{\left(\frac{s}{2\,C}\right)^2 + 1 - d_c} \qquad (2)$$

From (1) and (2), the required raising factors for single and pair trawlers respectively are found as the reciprocals of the calculated cover fractions d_s and d_p.

Since July 1958 it has been possible to divide the total catch from single and pair trawlers, respectively,

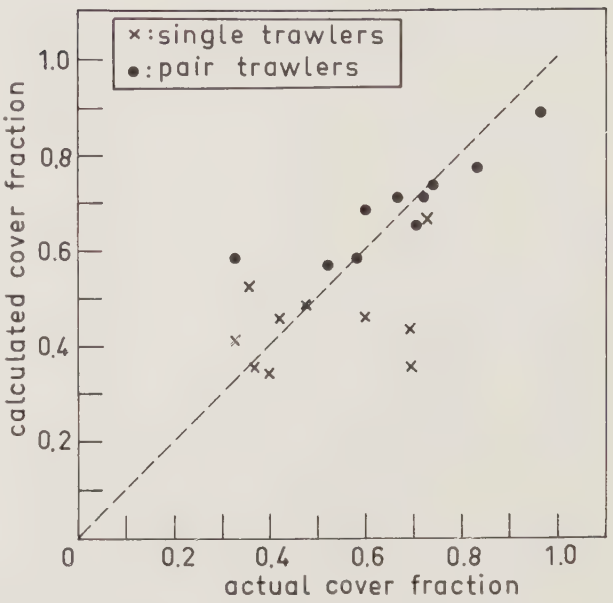


Figure 5. Comparison between calculated and actual cover fractions. Esbjerg. Autumn 1958. For explanation: see text.

and so obtain independent raising factors for each. It is further possible to compare values calculated from formulas (1) and (2) with the actual cover fractions. This was done on material from the autumn season 1958 and, as shown by Figure 5, there is sufficient agreement between the calculated and actual cover fractions to justify the use of the indirect method outlined above. The statistics from autumn 1957 and spring 1958 are treated accordingly, and it must be noted here that the stock assessment for the autumn of 1957, arrived at in this report is based on the total effort of both single and pair trawlers. In the preliminary report, Part III, presented to the Council in 1958, the stock assessment was based on the effort of pair trawlers only.

The total effort of pair trawlers is estimated directly, by applying the raising factors, calculated from the catch figures, to the reported effort.

The total effort of single trawlers is calculated by applying the single trawler raising factor to the reported effort, and converted into hours of pair trawling by the following conversion factors:—

av. catch per one hour's single trawling/av. catch per one hour's pair trawling.

The conversion factor is calculated for each season by summing the reported catch and effort for single and pair trawlers, respectively, using only statistical rectangles where both methods are used at the same time during the six or seven best weeks of fishing.

The following conversion factors were found:—

Table 4
Total catch and effort per week, Esbjerg, autumn 1957

Week No.	Dates	Total catch (1000 kg)	Total effort (pair trawling hours)
29	14/7 –20/7	3,409	2,444
30	21/7 –27/7	2,509	2,292
31	28/7 – 3/8	3,466	2,220
32	4/8 –10/8	4,733	4,387
33	11/8 –17/8	2,063	2,111
34	18/8 –24/8	4,310	2,783
35	25/8 –31/8	2,140	2,115
36	1/9 – 7/9	4,061	3,284
37	8/9 –14/9	1,545	1,317
38	15/9 –21/9	195	174
39	22/9 –28/9	4,913	3,032
40	29/9 – 5/10	2,260	2,343
41	6/10–12/10	1,004	1,322
42	13/10–19/10	2,214	2,905
43	20/10–26/10	197	223
44	27/10– 3/11	108	67
47	17/11–23/11	2,125	2,589
Total		41,252	35,608

Average catch per hour = 1,159 kg.

Autumn 1957. One hour's single trawling = 0·432 × one hour's pair trawling.

Spring 1958. One hour's single trawling = 0·424 × one hour's pair trawling.

Autumn 1958. One hour's single trawling = 0·567 × one hour's pair trawling.

The distribution of the effort per week is shown in Appendices 5 and 6, while total catch and effort figures are found in Tables 4, 5, and 6.

Table 5
Total catch and effort per week, Esbjerg, spring 1958

Week No.	Dates	Total catch (1000 kg)	Total effort (pair trawling hours)
6	2/2 – 8/2	2,221	1,725
9	23/2 – 1/3	2,416	1,476
10	2/3 – 8/3	3,054	1,564
11	9/3 –15/3	2,533	2,034
12	16/3 –22/3	3,158	2,225
13	23/3 –29/3	3,514	3,210
14	30/3 – 5/4	759	540
16	13/4 –19/4	2,876	2,035
17	20/4 –26/4	1,007	787
18	27/4 – 3/5	2,774	1,898
Total		24,312	17,494

Average catch per hour = 1,390 kg.

Table 6
Total catch and effort per week, Esbjerg, autumn 1958

Week No.	Dates	Total catch (1000 kg)	Total effort (pair trawling hours)
30	20/7 –26/7	166	197
31	27/7 – 2/8	616	1,078
32	3/8 – 9/8	3,900	2,692
33	10/8 –16/8	7,614	4,140
34	17/8 –23/8	4,996	2,596
35	24/8 –30/8	7,245	4,087
36	31/8 – 6/9	7,037	3,569
37	7/9 –13/9	8,007	3,786
38	14/9 –20/9	7,512	4,569
39	21/9 –27/9	3,348	2,284
40	28/9 – 4/10	1,366	857
41	5/10–11/10	4,300	2,553
42	12/10–18/10	717	435
43	19/10–25/10	1,078	401
44	26/10– 1/11	4,965	2,728
45	2/11– 8/11	4,981	2,520
46	9/11–15/11	1,683	902
47	16/11–22/11	2,628	1,708
48	23/11–29/11	1,701	1,192
Total		73,860	42,294

Average catch per hour = 1,746 kg.

German catch and effort statistics

According to the international programme, provisions were made in 1957 and 1958, in advance of the tagging experiments, to obtain the collaboration of the fishermen as well as the managers and workers of the fish meal factories. Several meetings were arranged at which the purpose and performance of the experiment were discussed. The written instructions, together with the statistical forms, were distributed to the fish meal factories by the kind co-operation of the "Verband Deutscher Fischmehl- und Fischölfabriken e. V." and to the fishermen by the "Deutscher Fischereiverband e. V" and the fisheries co-operatives. Each reduction plant was asked to support the experiment and was provided with posters and cards for returned tags and information. Furthermore, repeated references to the tagging experiment were given in the press and broadcasting. The whole preparatory work and the collection of statistics was organized by Dr. G. Krefft, Hamburg, the German member of the tagging group. The local arrangements, especially the efficiency tests for magnets in the reduction plants, were made by the local governmental biologists; Dr. C.-H. Brandes, Bremerhaven and Dr. H. Kühl, Cuxhaven, did most of this work.

Industrial herrings, caught by German cutters are landed at only 4 ports, nearly all in Cuxhaven and Bremerhaven, but the ports of Hamburg and Büsum are sometimes also supplied. Thus the collection of the statistics on the catches and fishing effort as well as on the deliveries at the reduction plants could be concentrated at the two main ports. The German landings given in Table 7 comprise an unknown amount of industrial herring caught outside the Bløden area, mainly west of the Dogger Bank. On the other hand, some unimportant catches of herring made during tunny and sprat fishing are not included.

Table 7
Industrial herring fishery landings from the Bløden Ground area in Germany in 1957

A. *Bremerhaven*

Week	Dates	Landings (tons)	Number of landings[1]) Cutters
27	30/6 – 6/7	90·0	(+)
28	7/7 –13/7	484·7	(10)
29	14/7 –20/7	532·1	(12)
30	21/7 –27/7	566·9	(18)
31	28/7 – 3/8	118·2	(8)
32	4/8 –10/8	1,460·7	(24)
33	11/8 –17/8	459·0	(6)
34	18/8 –24/8	767·2	(22)
35	25/8 –31/8	437·0	(11)
36	1/9 – 7/9	130·0	(3)
Grand Total		5,045·8	(114)

[1]) Not fully recorded.

B. *Cuxhaven*

27	30/6 – 6/7	91·0	6
28	7/7 –13/7	1,074·9	61
29	14/7 –20/7	501·9	28
30	21/7 –27/7	1,042·1	50
31	28/7 – 3/8	226·7	14
32	4/8 –10/8	2,074·4	89
33	11/8 –17/8	667·3	52
34	18/8 –24/8	1,560·3	74
35	25/8 –31/8	305·1	18
36	1/9 – 7/9	172·3	7
Grand Total		7,716·0	399

C. *Hamburg*

No landings.

D. *Büsum*

27	30/6 – 6/7	–	
28	7/7 –13/7	–	
29	14/7 –20/7	31·0	
30	21/7 –27/7	144·0	
31	28/7 – 3/8	–	Not recorded
32	4/8 –10/8	169·0	
33	11/8 –17/8	116·0	
34	18/8 –24/8	74·0	
35	25/8 –31/8	57·0	
36	1/9 – 7/9	–	
Grand Total		591·0	

Grand Total of landings in all ports (A + B + C + D) = **13,352.8 tons.**

The best estimate of industrial herring landings from the true Bløden Ground may be taken for 1957 and 1958 from the data on herring reduction in the fish meal factories given in Tables 7 and 8.

In 1957, it was possible to obtain data on deliveries of industrial herring each week at nearly all factories in Cuxhaven, Bremerhaven, and Büsum from the daily statistics of these plants (Table 7). Data on the number of cutters landing each week were also

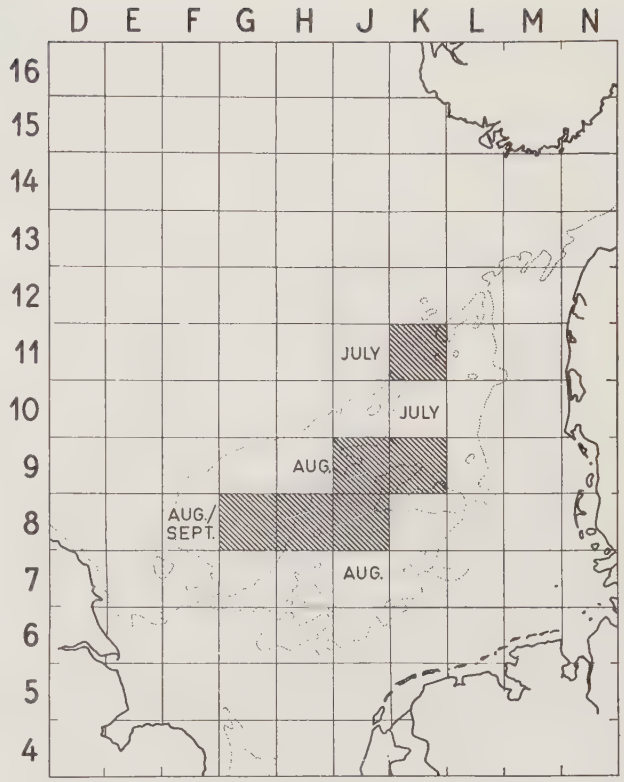


Figure 6. Main areas of the German fishery for industrial herring during the Bløden Ground season 1957.

available, at least for Cuxhaven. Unfortunately, in 1957 the first attempt to build up detailed statistics on the catches of the oil herring cutters and their corresponding effort by rectangles did not result in data sufficient for any assessments.

The 1957 German cutter season started at the end of June, week 27, in the Coffee Soil area (square K 11). During July, this fishery was mainly carried out at the N-Schill-Ground (square K 9), whereas during August fishing took place in the squares I 9, K 9, and primarily G, H, I 8 (see Figure 6). At the beginning of September, about week 37, the German fleet shifted to fishing grounds further west and outside the Bløden area, e. g. the outer Silver Pit, SW-Pit, Brucey's Garden and the area off North Shields and Blyth, where adult herrings were mainly caught. The proper oil herring fishery for juvenile herrings in the Bløden Ground in 1957 had ceased by 5. September. The total landings of about 13,500 tons were low compared with the landings of the preceding years. This is mainly due to the very bad weather conditions in 1957, and partly to the minor participation of German cutters in this fishery during this year.

Table 8
Industrial herring fishery landings from the Bløden Ground area in Germany, and catches reported from German ships in 1958

(Data in brackets: number of reporting ships)

A. *Bremerhaven*

Week	Dates	Landings to factories: Landings (tons)	Landings to factories: Number of landings Cutters	Catches reported from ships: Single trawlers (tons)	Catches reported from ships: Pair trawlers (tons)
28	6/7 –12/7	71·4	4	–	71·4
29	13/7 –19/7	–	–	–	95·5
30	20/7 –26/7	323·1	13	12·9	209·1
31	27/7 – 2/8	–	–	–	187·9
32	3/8 – 9/8	295·4	14	–	259·5
33	10/8 –16/8	893·8	28	–	720·6
34	17/8 –23/8	700·7	18	79·5	1,044·5
35	24/8 –30/8	951·4	22	25·7	917·7
36	31/8 – 6/9	1,002·1	30	28·1	750·6
37	7/9 –13/9	982·2	22	56·2	1,236·6
38	14/9 –20/9	1,578·7	33	5·0	1,114·9
39	21/9 –27/9	710·6	16	–	331·8
40	28/9 – 4/10	193·1	8	9·0	891·7
41	5/10–11/10	898·6	27	20·7	206·8
42	12/10–18/10	334·8	16	–	194·0
43	19/10–25/10	–	–	21·2	286·3
44	26/10– 1/11	274·3	6	–	–
45	2/11– 8/11	4·1	1	–	–
Grand Total		9,214·3	258	258·3 (14)	8,518·9 (234)

Grand Total of catches reported from ships: – 8,777·2 tons = 95·3 % of total landings.
Total number of reporting ships 248 = 96·1 % of number of landings.

B. *Cuxhaven*

28	6/7 –12/7	43·0	2	–	45·0
29	13/7 –19/7	–	–	–	102·5
30	20/7 –26/7	346·0	20	–	141·0
31	27/7 – 2/8	115·0	7	–	243·0
32	3/8 – 9/8	500·0	29	3·0	339·6
33	10/8 –16/8	1,691·0	50	136·0	655·5
34	17/8 –23/8	1,132·0	42	85·0	1,424·0
35	24/8 –30/8	1,770·0	51	113·0	1,057·3
36	31/8 – 6/9	1,830·0	57	207·0	570·6
37	7/9 –13/9	2,320·0	68	336·0	1,400·0
38	14/9 –20/9	2,248·0	57	651·0	1,290·0
39	21/9 –27/9	1,178·0	40	15·0	95·0
40	28/9 – 4/10	632·0	27	166·0	583·0
41	5/10–11/10	948·0	35	73·0	134·5
42	12/10–18/10	387·0	21	–	45·0
43	19/10–25/10	3·0	1	–	–
44	26/10– 1/11	42·0	1	–	–
45	2/11– 8/11	72·0	4	–	–
46	9/11–15/11	7·0	1	–	–
47	16/11–22/11	–	–	–	–
48	23/11–29/11	47·0	1	–	–
Grand Total		15,311·0	514	1,785·0 (62)	8,126·0 (252)

Grand Total of catches reported from ships: – 9,911·0 tons = 64·7 % of total landings.
Total number of reporting ships 314 = 61·1 % of number of landings.

Table 8 (continued)

C. *Hamburg*

Month	Landings to factories: Landings (tons)	Landings to factories: Number of landings Cutters	Catches reported from ships: Single trawlers (tons)	Catches reported from ships: Pair trawlers (tons)
August	206·7	8	–	–
September	368·0	20	–	–
October	280·4	10	–	–
Grand Total	855·1	38	– (–)	– (–)

D. *Büsum*

No landings.

All ports (A–D):

Total landings A to D = 25,380·5 tons
Total reported catches = 18,688·2 tons = 73·6 %
Total number of landings A–D = 810 cutters
Total number of reporting ships = 562 (cutters) = 69·4 %

In 1958, the statistics for the fish meal factories were collected in the same manner as in 1957. From the data on the daily processed quantities and number of landings in each reduction plant, the weekly review given in Table 8 was prepared. The catch and effort statistics in this year were collected by the State Fishery Office of Bremen and Niedersachsen acting as fishery control authority in Bremerhaven and Cuxhaven. This procedure proved to be suitable, so that these statistics could be prepared better than in the preceding year. The data on the reported catches and numbers of landings split up by landing harbours, weeks, and fishing gear, are also given in Table 8. The distribution of effort for each week per statistical rectangle is shown in Appendix 6.

In compiling these statistics some conversions had to be made. Most of the German cutters are engaged in pair trawling. Of the reported catches 88·8 % were made by pair trawling. As the trawling with a single boat is only of minor importance, and the total amount of herring delivered each week in the factories is not statistically sub-divided by landings of single and pair trawlers, it was decided to combine the data for both types of gear. Thus, the effort of the single trawlers had to be corrected, because German investigations have shown that the fishing capacity of the pair trawlers is about 11 % greater than of the single trawlers. As the unit of effort for the calculations, hauls of pair trawlers were used. The formula used for the conversion of the single trawlers' effort to that of pair trawlers was:— 1 single trawler haul = 0·445 double trawler haul. The reported pair trawler effort for each week was then combined with the corresponding corrected single trawler effort. The total effort of the vessels from Cuxhaven and Bremerhaven was estimated by raising the reported effort for each harbour and each week by the ratio: total catch/reported catch. It was found that there were no differences in the fishing areas of the cutters from the two harbours. Therefore, the total German effort was estimated by adding the raised effort data for each harbour.

The 1958 season of the German industrial herring fishery began at the end of June and did not end until the first week of November. It lasted much longer than the 1957 season. The total landings from the Bløden area, amounting to nearly 25,400 tons were much bigger than in 1957. The better results were partly due to the more favourable weather conditions, but mainly to the strong increase in the catch per unit effort, the average of which was 19·4 tons per trip in 1957 and 29·8 tons in 1958. (In 1959 the mean catch per trip of the German vessels further increased to 32·5 tons (Ref. 13)). It has to be noted also, that in 1958 a substantial part of the landings, especially of those taken during the weeks 36—38, came from outside the Bløden area, mainly from the Middle Rough. According to investigations made on board F. R. S. "Anton Dohrn", the dense schools of immature herring found in October 1958 in that area did not belong to the same stock as the immatures from the Bløden Ground, as they were quite different in composition and meristic characters.

VI. The Returns

Tagging mortality

It is impossible to guarantee that all fish tagged survive the shock of being tagged. At the same time it was equally impossible to measure such mortality directly. But it might be expected that the larger fish survived better than the small ones. If it was so it might be expected that the mean length at liberation of the recaptured fish should be larger than the mean of all the tagged fish. In Table 9 is given the length distribution of the tagged and recaptured fish, together with the means and variances. All the figures are from the 1958 experiment as no length measurements were taken in the 1957 experiment. The differences between the means are all small and far from being significant both separately and combined. It is, however, easy to think of a mechanism which gives unaltered means even if the smaller fish have a higher tagging mortality than the larger ones. If the small fish die and the large emigrate in the right proportions, one would find the same mean in the tagged and the recaptured population, but one should expect to find the smaller variance connected with the recaptures. From Table 9 it is seen that the recapture variances of two of the five liberations (III and IV) are significantly smaller than the corresponding tagging variances. A combination of the five tests, however, gives that it might have occurred by chance.

There are in this way no clear indications of a relation between the length of a fish and its chance of being recaptured, and in the later calculations it is supposed that the chance of recapture is independent of the size of the fish.

The recovery of two tags in the stomach of whiting suggests that one form of tagging mortality during the Bløden experiment was due to predators while the herring were recovering from the shock of tagging, and were less active. In fact, considering how slight must be the chances of finding a tag in the stomach while gutting a whiting, this form of mortality might well be considerable. If it does occur it would probably be higher among those fish kept longest in the keep nets.

In Appendix 7 the total recaptures from each liberation have been summarized, according to the tagging team and the time between capture and tagging. For the latter, the fish tagged by each team have been divided into ten groups:— group 1 includes the first fish tagged, group 10 the last, up to five hours after group 1. It will be seen that, especially for the 1958 experiment, there were large differences in recaptures both between tagging teams and between groups of fish. In all the 1958 liberations, the highest percentage of recaptures was from team 1, though the ratio of recaptures from the different teams was not the same in all experiments. There were, also, more returns from the fish tagged earlier in each liberation (groups 1—5) than those for which there was some delay in tagging (6—10), though again the differences varied from liberation to liberation, being greatest for liberation I.

For the 1957 experiment there was no significant difference between fish kept for different length of time, though there were differences between tagging teams. These latter are not so clear as in 1958, because the same tagging teams were not maintained from one experiment to another.

It is reasonable to assume that these differences are due to losses at tagging, either because of handling differences, incorrect placing of the tag in the body cavity (causing death or loss of tag), or loss of condition while in the keep net. All these factors will reduce the effective number of fish tagged.

While it is impossible to determine the extent of these losses, some estimates, which will make some correction for the effects, can be made. For the 1957 experiment no correction is made for the time between capture and tagging, but it will be assumed that the differences between the best team for anyone liberation and the other teams, are due to mortality or loss of tags, so that the effective number of fish tagged will be as given below:—

Liberation	I	II	III
% returned by best team (A)	7·2	9·2	2·7
Total tags returned (B).....	215	162	82
Effective number tagged B/A × 100.....	3,000	1,760	3,000

For the 1958 experiment, team 1 is taken as standard, except for liberation S VI. In Figure 7 the returns of this team have been plotted against time between capture and tagging. These points show a very close relation, and the line fitted by least squares has been plotted. The intercept on the y-axis ($= 23{\cdot}5$) may be taken as a fair estimate of the returns to be expected from a group of fish tagged with no delay at all between capture and tagging. Thus the returns to be expected if there was no delay for any of the 10 groups of fish is 235, compared with an observed total of 172; the "expected" returns of fish tagged by team 1 are therefore $235/172 = 1{\cdot}366$ times the observed number.

A different formula has to be used for liberation S VI, in which team 1 did not participate. For this liberation team 3 has been taken as standard, and the "efficiency" of this team estimated from percent-

Table 9
Liberations

Length at Liberation (cm)	I		II		III		S VI		IV	
	No. of fish tagged	No. of fish recapt.	No. of fish tagged	No. of fish recapt.	No. of fish tagged	No. of fish recapt.	No. of fish tagged	No. of fish recapt.	No. of fish tagged	No. of fish recapt.
23	–	–	–	–	–	–	–	–	–	–
21·5	–	–	–	–	–	–	2	–	1	–
22	–	–	–	–	–	–	1	–	–	–
21·5	–	–	–	–	–	–	4	–	2	–
21	–	–	–	–	–	–	6	–	1	–
20·5	–	–	–	–	–	–	8	–	5	–
20	–	–	–	–	1	–	11	–	7	–
19·5	2	–	–	–	1	–	24	1	16	–
19	2	–	–	–	2	–	64	3	45	2
18·5	10	1	2	1	12	–	120	2	71	5
18	47	3	16	1	61	5	189	15	259	10
17·5	121	9	87	7	109	11	223	10	512	17
17	255	21	389	30	254	28	163	6	905	27
16·5	326	27	454	27	251	21	131	1	578	18
16	410	30	438	30	275	18	31	–	342	10
15·5	186	17	95	7	93	7	9	–	34	–
15	99	11	16	–	29	–	1	–	8	1
14·5	26	1	3	–	3	–	–	–	3	–
14	2	–	1	–	–	–	–	–	–	–
13·5	–	–	–	–	–	–	–	–	–	–
13	1	–	–	–	–	–	–	–	–	–
Total.....	1,487	120	1,501	103	1,091	90	987	38	2,789	90

$\bar{X}_{tagged} = 16{\cdot}33$ $\bar{X}_{tagged} = 16{\cdot}48$ $\bar{X}_{tagged} = 16{\cdot}58$ $\bar{X}_{tagged} = 17{\cdot}68$ $\bar{X}_{tagged} = 17{\cdot}04$

$\bar{X}_{recapt.} = 16{\cdot}30$ $\bar{X}_{recapt.} = 16{\cdot}53$ $\bar{X}_{recapt.} = 16{\cdot}68$ $\bar{X}_{recapt.} = 17{\cdot}82$ $\bar{X}_{recapt.} = 17{\cdot}10$

$s^2_{tagged} = 0{\cdot}65$ $s^2_{tagged} = 0{\cdot}32$ $s^2_{tagged} = 0{\cdot}57$ $s^2_{tagged} = 1{\cdot}02$ $s^2_{tagged} = 0{\cdot}59$

$s^2_{recapt.} = 0{\cdot}62$ $s^2_{recapt.} = 0{\cdot}34$ $s^2_{recapt.} = 0{\cdot}42$ $s^2_{recapt.} = 0{\cdot}41$ $s^2_{recapt.} = 0{\cdot}57$

Test for means: –

$$u_I = \frac{-0{\cdot}03 \times \sqrt{120}}{\sqrt{0{\cdot}65}} = -0{\cdot}49 \qquad u_{II} = \frac{0{\cdot}05 \times \sqrt{103}}{\sqrt{0{\cdot}32}} = +1{\cdot}05$$

$$u_{III} = \frac{0{\cdot}10 \times \sqrt{90}}{\sqrt{0{\cdot}57}} = +1{\cdot}34 \qquad u_{SVI} = \frac{0{\cdot}14 \times \sqrt{38}}{\sqrt{1{\cdot}02}} = +0{\cdot}80 \qquad u_{IV} = \frac{0{\cdot}06 \times \sqrt{90}}{\sqrt{0{\cdot}59}} = +0{\cdot}78$$

Combined tests: –

$$u = \frac{\Sigma u_i}{\sqrt{5}} = 1{\cdot}56 \quad \chi^2 = \Sigma (u_i - \bar{u})^2 = 1{\cdot}97$$

Tests for variances: –

$$\chi^2_I = 119 \times \frac{0{\cdot}62}{0{\cdot}65} = 114; \quad \chi^2_{II} = 102 \times \frac{0{\cdot}34}{0{\cdot}32} = 108; \quad \chi^2_{III} = 89 \times \frac{0{\cdot}42}{0{\cdot}57} = 66; \quad \chi^2_{SVI} = 37 \times \frac{0{\cdot}41}{1{\cdot}02} = 15;$$

$$\chi^2_{IV} = 89 \times \frac{0{\cdot}57}{0{\cdot}59} \quad 87.$$

Combined tests: –

$$\chi^2 = \Sigma \chi^2_i = 390; \quad df = 436$$

$$(\chi^2_p = 0{\cdot}05 \approx \tfrac{1}{2} (\sqrt{2f-1} - u_{0{\cdot}05})^2 = 388)$$

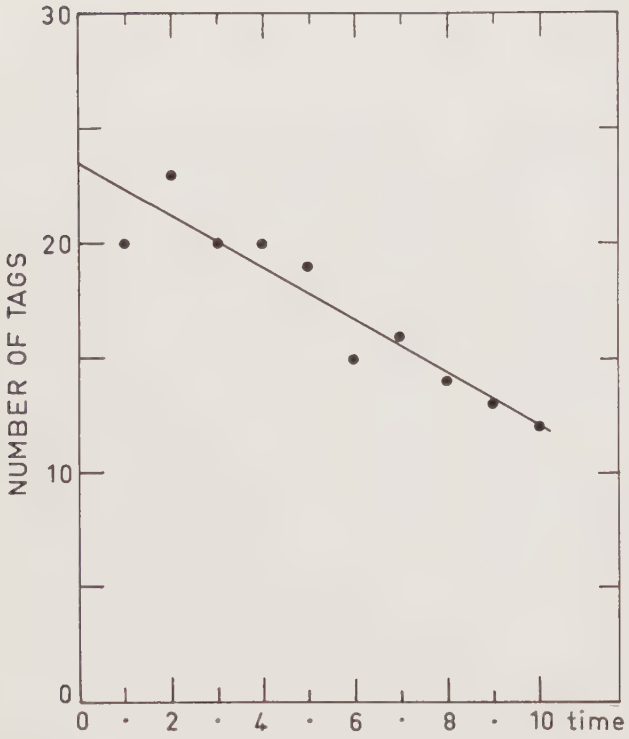


Figure 7. Returns of team 1 plotted against time between capture and tagging.

age returns of teams 1 and 3 from all other liberations; viz. for team 1, from 2,100 fish tagged, 172 were recaptured, or a percentage of 8·19; for team 3, from 2,300 fish tagged, 124 were recaptured, or a percentage of 5·39. From team 3's liberations in liberation S VI, 4·0 % were returned; this is, therefore, equivalent to $4{\cdot}0 \times 8{\cdot}19/5{\cdot}39 = 6{\cdot}08$ % from team 1, or $6{\cdot}08 \times 1{\cdot}366$ % = 8·305 % corrected for delay in tagging.

The tagging conditions for liberation S VI were, in fact, rather different from the other liberations, the fish being tagged on board after being transferred from the keep net to buckets. The actual mortality at tagging is likely to be different from that estimated here, and probably larger. This might explain the rather low value of number of tags/100 hours' fishing per square/1000 tags for liberation S VI, as estimated later in this report.

The estimates for all liberations can, therefore, be determined as in Table 10.

Efficiency of magnets

Not all the tags from recaptured fish are returned; some fish are processed at factories not equipped with magnets, and some tags are not detected by the magnets. This loss was estimated by measuring the returns from a known number of tagged fish introduced into each factory. The efficiency of return for each factory, weighted by the quantity of fish processed by the factory gives the average efficiency for that port or country. This factor is then applied to the number of tags (or tags per unit effort) reported, to give an estimate of the actual numbers caught. The estimated percentages of recaptured tags actually returned were as follows:—

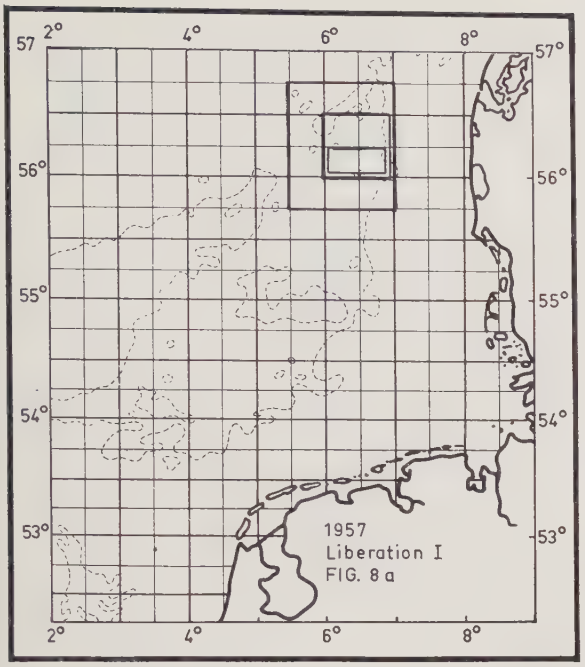
Esbjerg	1957	88 %
Germany	1957	74 %
Esbjerg	1958	91 %
Germany	1958	64 %

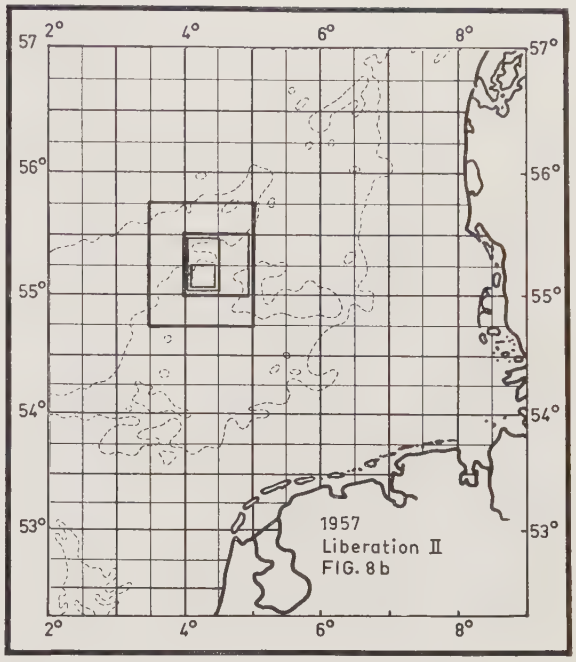
Early returns from Esbjerg

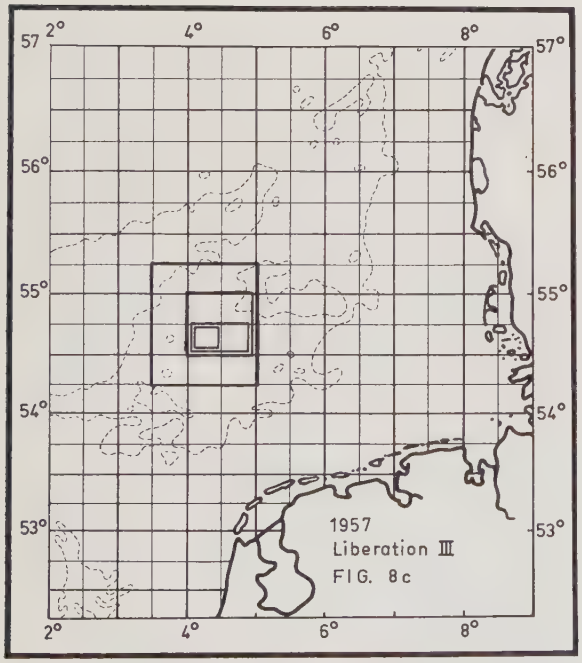
Appendix 8 shows that the total returns and their distribution by weeks and between ports varied greatly from liberation to liberation. The most reasonable explanation is that during the period of time concerned, there was relatively little mixing between the groups of fish tagged. The internal tags cannot show this directly, because the tag may not reach the magnet and be recovered until some time has passed, and cannot, with certainty, be allocated to a particular day of landing, still less to a particular cutter.

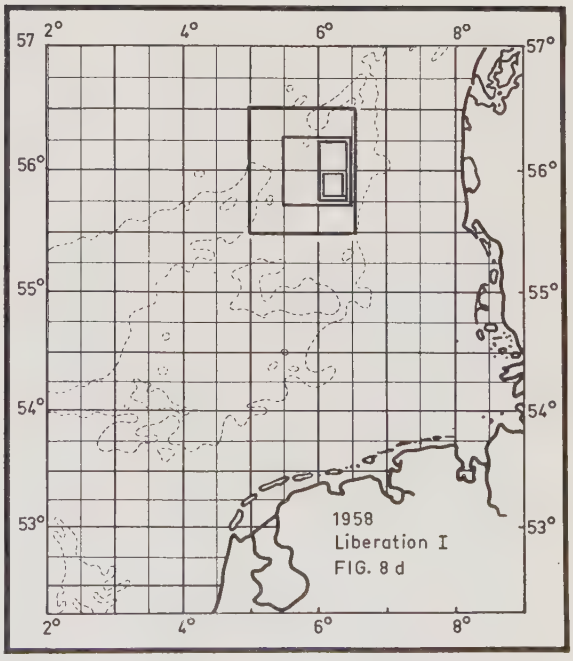
Table 10
Estimates of the effective number of herring tagged

	Fish tagged by standard team			All fish		
Liberation	Tagged	Recaptured %	Recaptured (A) corrected for delay (%)	Actually tagged	Recaptured (B)	Effective no. tagged (B/A × 100)
I	550	9·5	13·0	1,500	120	930
II	450	11·1	15·2	1,507	103	680
III	250	13·2	18·0	1,094	91	500
S VI	600	6·1	8·3	1,000	39	470
IV	850	4·3	5·9	2,800	90	1,510
			Total...	7,901	443	4,090

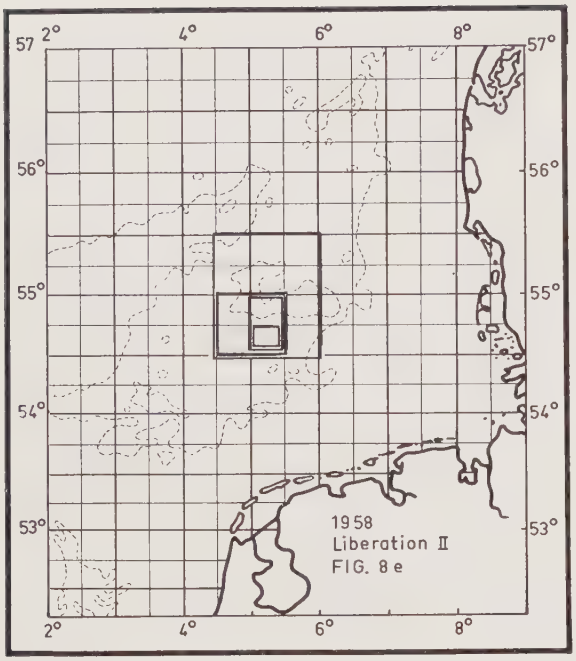


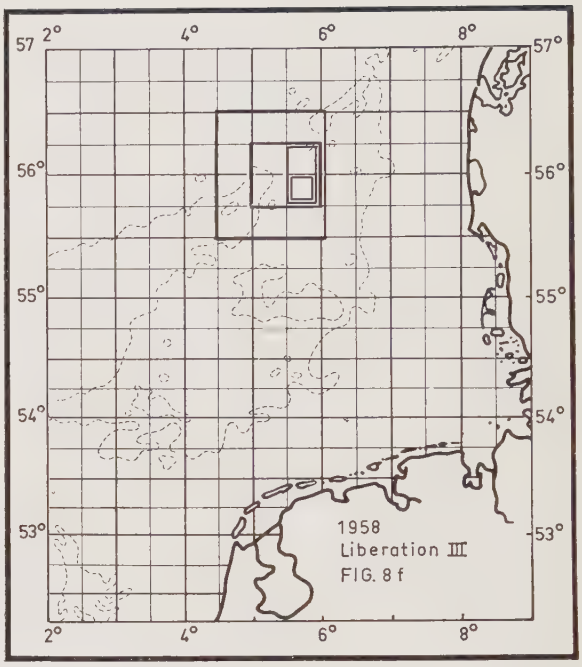


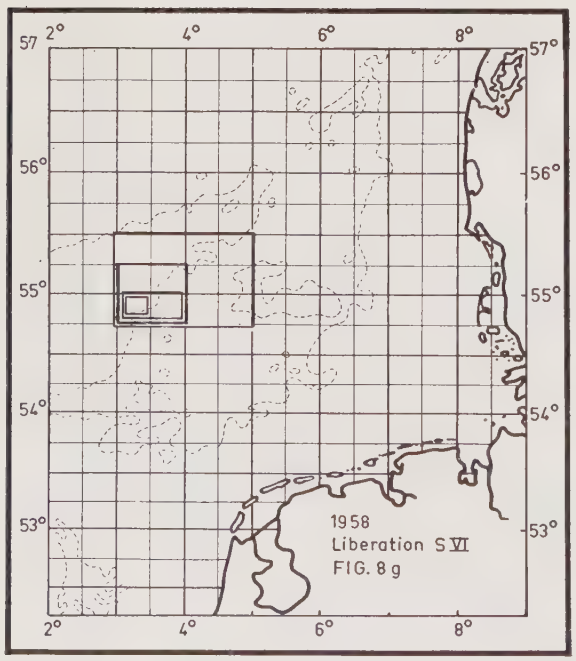




Figures 8 a-h. The regions of 1, 2, 4 and 12 squares used in calculating the fishing intensity on each liberation of tags.


1958
Liberation II
FIG. 8 e


1958
Liberation III
FIG. 8 f


1958
Liberation S VI
FIG. 8 g

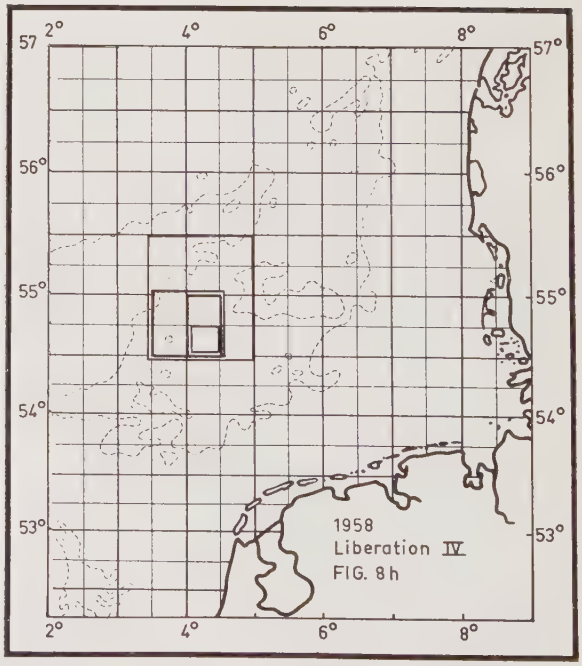

1958
Liberation IV
FIG. 8 h

Table 11
Weighting factors used to determine average fishing intensity

Week after tagging:	1	2	3	4	5	6	7	8
1.-square region.....	0·8	0·6	0·3	0·1	0·1	0·1	0·0	0·0
2.-square region.....	0·1	0·2	0·3	0·3	0·1	0·1	0·1	0·1
4.-square region.....	0·05	0·1	0·2	0·3	0·3	0·2	0·1	0·1
12.-square region.....	0·05	0·1	0·2	0·3	0·5	0·6	0·8	0·8

There are exceptions for which movement can be clearly shown, where a tag is returned from a port whose fleet does not fish in the tagging area. However, for the bulk of the returns from ports whose ships have been fishing both in the marking area and elsewhere, we may strongly suspect that the tags coming back in the first few weeks were nearly all caught close to the tagging position, but from the evidence of internal tags alone, there is no direct way of proving it.

The analysis of the results, therefore, depends largely on calculating the local fishing intensity on each group of tagged fish. This requires detailed effort statistics by areas and some assumption about the movements and dispersal of the tagged fish.

For the Esbjerg statistics, which are given for areas, 15 miles square, the average effort per square was calculated for 4 areas of differing sizes (1, 2, 4, and 12 squares) surrounding the tagging position. (For liberation I of 1957, which was nearly on the border between two squares, the smallest area was not used.) The particular squares used are shown in Figures 8 a–h, the choice being determined by the *probable general movement* from the liberation position. Finally, the best estimate of the fishing intensity on the tagged fish is found as the weighted mean of the intensities in the four areas. For the first week after tagging, greatest weight is given to the single square, covering the marking area, and in later weeks increasing weight is given to the other areas. With our present information the weights used must be purely arbitrary, and those actually used are given in Table 11. The weights for liberation I of 1957, for which no single square region was used, were obtained by adding the first two weights.

These weighting factors define the dispersal of fish from the tagging position, and the assumed pattern of distribution of 10,000 tagged fish is shown in the following diagram:—

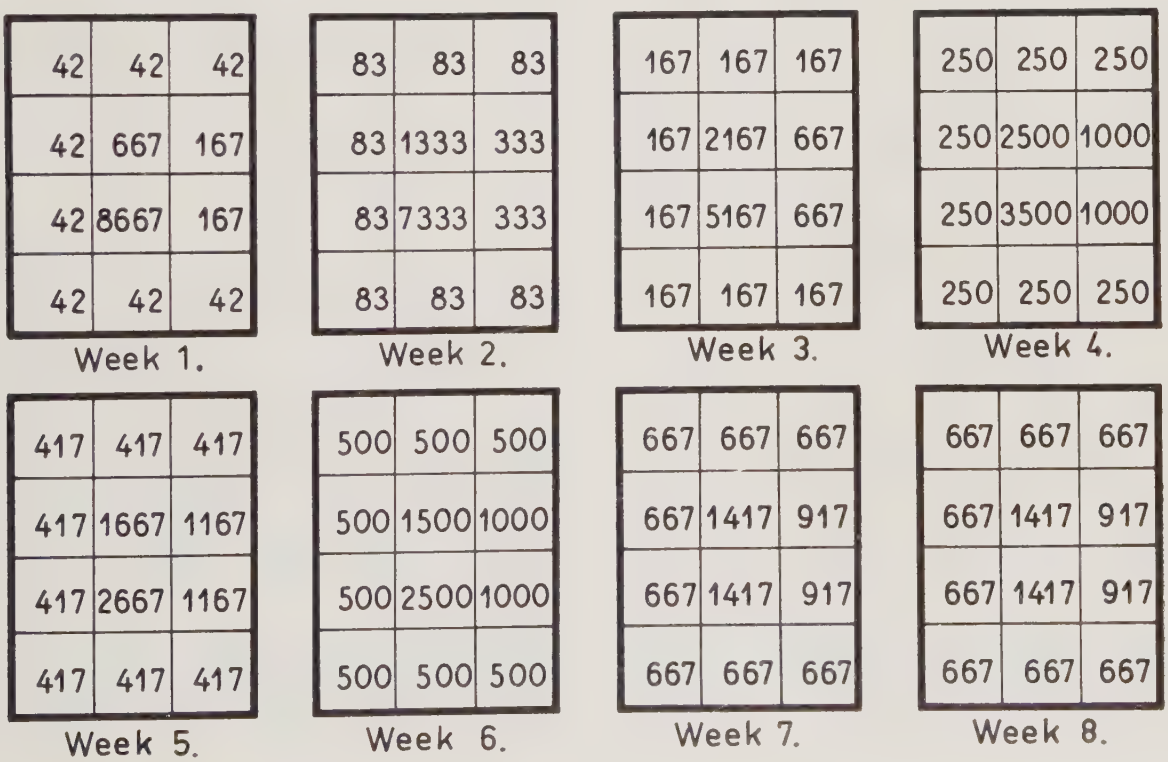


Table 12
Number of tags returned per unit fishing intensity per 1000 fish effectively tagged

	1957			1958				
Week	I	II	III	I	II	III	S VI	IV
32	(8·9)	–	–	–	–		–	–
33	24·6	–	–	(2·5)	(0)	–	–	–
34	26·7	(10·6)	16·7	17·8	0	(25·0)	–	–
35	6·7	3·1	22·2	2·0	0	10·9	8·9	(0)
36	3·3	1·6	48·5	7·2	4·8	14·3	15·0	26·1
37	5·8	2·7	16·7	7·3	20·1	14·0	6·6	7·4
38	–	0	–	4·3	11·4	14·2	18·5	0
39	22·0	34·1	–	5·9	61·9	19·2	6·8	20·4
40	–	–	–	9·8	0	12·9	0	2·0
41	–	–	–	–	–	44·4	0	39·1
42	–	–	–	-	–	–	–	–
Total for 8 weeks	15·02	9·82	31·37	8·70	19·45	15·76	7·16	14·80

The number of tags returned per unit fishing intensity (100 hours' fishing per square) per 1,000 fish tagged can be calculated for each liberation for each week. The figure used for the number of fish tagged was that derived above, corrected as far as possible for loss at tagging. These calculations are given in detail in Appendix 9. For all except the first week after tagging, the data have been smoothed by using the mean of the effort in the week of reported recapture and in the previous week; this, in part, corrects for the delay which, as shown by the tests, often occurs between the tagged fish entering the factory, and the appearance of the tags at the magnets. The results are summarized in Table 12.

The figures in brackets denote the values for the week in which tagging took place, and in which, therefore, the tagged fish were not subject to the full effort. A single estimate (bottom row) for each liberation was obtained by adding the number of tags and fishing intensity for the 8 weeks, and is given by: –

$$p = \frac{\Sigma n}{\mathcal{N}\Sigma f}$$

where p = returns per unit intensity per 1000 fish tagged;
n = number of tags returned each week;
$\mathcal{N}$ = total number of fish effectively tagged;
f = fishing intensity in each week.

This shows a fair degree of agreement between the liberations and between years. A single figure for tags per fishing intensity can be given as the simple mean of all liberations (in the year) or, probably better, as the mean, weighted by the effective number of fish tagged in each liberation × the total fishing effort on those fish, that is, the mean value for all experiments in the year is: –

$$p = \frac{\Sigma\,(\Sigma n)}{\Sigma\,(\mathcal{N}\Sigma f)}$$

This gives values of 12·8 for the 1957 experiment and 11·4 for 1958.

Strictly, some allowance should be made for mortality (other than that caused directly by tagging) between the time of tagging and recapture. This should appear as a decrease in the number caught per unit effort with time. The data are too variable to detect such a decrease with any certainty, but there are some suggestions of it, at least for liberations I/1957 and I/1958. To the extent that it does occur, then the present estimates are underestimates of the actual rate of capture immediately following tagging.

Using the weighted means for all weeks the expected number of recaptures from each liberation each week can be calculated, and in Table 13, these are compared with the numbers actually observed.

Though the differences between "observed" and "expected" are larger than would be expected by random variation alone, the general agreement is reasonable, considering the methods used and the inevitable inaccuracies in the original data, such as fishing positions, etc. The most serious differences are in liberation I, 1958, for which the number returned, particularly in the later weeks, were well below expectation, and in the last two weeks for liberation II, 1958. These differences are probably due to the dispersion of the fish from the tagging position, differing from the rather simple pattern assumed. Liberation I, 1958, was made on the edge of the main Bløden Ground. It is possible that these fish, instead of moving mainly north and west from the tagging area, moved north-east. This would take them out of the area fished by the Esbjerg fleet. That this may have happened is supported by the 4 returns from this liberation by the Thyborøn fishery

Table 13
Number of recaptures observed and expected each week from each liberation

1957 *Liberations*

Week	I		II		III	
	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
32	(21)	(30)	–	–	–	–
33	53	25	–	–	–	–
34	48	21	(79)	(96)	(3)	(2·3)
35	8	10	12	3	3	1·2
36	4	22	2	28	8	3·1
37	7	9	3	0	2	0
38	0	0	0	1	0	0
39	10	12	3	2	0	0

1958 *Liberations*

Week	I		II		III		S VI		IV	
	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
33	(13)	(58)	(0)	(0·1)	–	–	–	–	–	–
34	65	25	0	0	(1)	(0·5)	–	–	–	–
35	4	20	0	0·6	6	12	(1)	1	(0)	(0·3)
36	8	5	1	4	11	5	3	3	12	10
37	4	7	8	5	7	6	1	0·2	4	2
38	5	19	4	3	14	16	1	1	0	2
39	6	4	12	1	16	3	1	2	8	7
40	2	1	0	0·5	2	1	0	1	1	4
41	–	–	–	–	8	3	0	1	13	3
42	–	–	–	–	–	–	–	–	–	–

in weeks 35, 36, 39, and 41. If this explanation is accepted, and the estimates for liberation I, 1958, is too low, then a better estimate for the whole year is the mean of the estimates for liberations II, III, S VI, and IV = 15·1 tags/100 hours/1000 tags.

These estimates must be corrected for the efficiency of the Esbjerg magnets (see page 18). These revised estimates are as follows:—

1957 ..... = 12·8/0·88 = 14·6 tags/100 hours/1000 tags
1958 (all liberations) = 11·4/0·91 = 12·5 tags/100 hours/1000 tags
1958 (liberations II, III, S VI, and IV)..... = 15·1/0·91 = 16·6 tags/100 hours/1000 tags

These figures show that a fishing intensity of 100 hours/square will catch probably between 1·25 % and 1·66 % of the stock present. During the periods of tagging, weeks 32—34 in 1957 and 33—35 in 1958, the average catches per 100 hours' fishing were 122 tons and 184 tons, respectively. These represent 1·46 % and 1·25 % (or 1·66 %) of the stock present per square. The estimates of the density of the stock are therefore:—

1957 ..... = 122/1·46 × 100 = 8,400 tons/square
1958 (all liberations) = 184/1·25 × 100 = 14,700 tons/square
1958 (liberations II, III, S VI, and IV)..... = 184/1·66 × 100 = 11,100 tons/square

Immediately before the tagging, echo-surveys were made over the Bløden Ground (Figures 1 and 2). Although there might have been fish where no traces were observed, and some traces might not have belonged to the Bløden stock proper (e. g., to 0-group fish), these surveys do provide a fair guide to the extent of the area covered by the stock. This gives a value of about 50 squares. The total number of squares fished at any time during the season (probably an overestimate of the extent of the stock at any one time) was about 60, while the greatest number fished in a single week (almost certainly an underestimate of the extent) was 35; these agree reasonably well with the figure of 50 squares. If the density throughout these 50 squares was the same, then the estimated sizes of the stocks at the time of tagging are:—

1957 ..... = 50 × 8,400 = 420,000 tons
1958 (all liberations) = 50 × 14,700 = 735,000 tons
1958 (liberation II, III, S VI, and IV)..... = 50 × 11,100 = 555,000 tons

Other Danish ports

Only a few tags (31 in all) were returned from Danish ports other than Esbjerg (mainly Thyborøn) in the period soon after tagging. These are too few

Table 14
Number of hauls by German cutters in the 30×30 m.sq. of liberation, and number of tags returned

1958 *Liberations*

Week	I		II		III		S VI		IV	
	Hauls	Tags	Hauls	Tags	Hauls	Tags	Hauls	Tags	Hauls	Tags
33	–	–	–	–	–	–	–	–	–	–
34		–	–	–	22	–	–	–	–	–
35		–	–	–	–	–	591	–	38	2
36	–	–	16	–	11	–	220	20	101	15
37	–	–	–	–	–	–	16	–	14	5
38		–	–	–	–	–	104	–	68	2
39	–	–	–	–	–	–	–	1	23	7
40	–	–	–	1	–	–	103	–	11	–

for detailed analysis, but, being predominantly from liberation I/1957, and a few from I/1958, they are in agreement with the general picture of the movements and slow dispersal of the groups of tagged fish.

German recaptures

Detailed German statistics of catch and effort are available only for 1958 in 30 × 30 miles squares. These cannot be combined directly with the Esbjerg figures in 15 × 15 miles squares, nor can the same areas round the liberation position be used to estimate fishing intensity. Instead the fishing effort, in terms of number of hauls, in the square in which the fish were liberated, was used for the 8 weeks following liberation. The data are given in Table 14.

As may be expected from these data the results are much more variable than those for the Esbjerg fleet. Pooling the data for the whole period (weeks 35—40) the last two liberations give the following results:—

	Liberation S VI	Liberation IV
Hauls	1,033	255
Tags recovered	21	31
Tags/100 hauls	2·0	12·0
Fish effectively tagged	470	1,510
Tags/100 hauls/1000 tags	4·33	8·05

The mean of these is 5·97 tags/100 hauls/1000 tags. This figure may be too low, as the low value for liberation SVI is due to the high effort in week 35, which was probably not in exactly the same area as the liberation. Tests of magnets showed that 64 % of all tags landed in Germany should be returned (see page 18). That is, the corrected number of tags is 5·97/0·64 = 9·33 tags/100 hauls/1000 tags. During the tagging period (week 35) the average catch per 100 hauls of the German cutters was 367 tons. The estimated density of stock at that time is therefore:

$$367 \times \frac{1000}{9{\cdot}33} = 39{,}400 \text{ tons per } 30 \times 30 \text{ miles square,}$$

or, in the same units as the Esbjerg estimate, 9,850 tons per 15 × 15 miles square, and 50 × 9,850 = 492,000 tons for the whole stock.

Late autumn recaptures

After more than 8 weeks, following tagging, the fish have probably moved too far from the tagging position to allow a local fishing intensity on them to be calculated by the above methods. However, it would seem that the various groups of fish had still not mixed very much, as is shown by the difference in the returns from the different liberations. This is clearer for the 1958 season, which continued longer than in 1957. It is impossible to determine exactly how the fish had moved. If the distribution of fishing (Appendix 6) is compared with the returns (Appendix 8), it will be seen that the fishing effort and number of returns agree, if the movements of each group of fish in 1958 were roughly as follows:—

Liberation I: Mainly north and east, perhaps as far as the entrance to the Skagerak.
Liberation II: north to the Tail-End of the Dogger.
Liberation III: no great movement; dispersion to the north-west and north-east.
Liberation S VI: north-east along the south edge of the Dogger Bank, and directly, or round the Tail-End, to the north-west side of the Dogger Bank.
Liberation IV: north and north-east.

Although it is not known whether these were necessarily the movements of the fish, they are in conformity with the pattern of returns, and are consistent with our present knowledge of the movements of the immature herring. In the absence of reliable data on local fishing intensity, a reasonable estimate of the stock size at the time of tagging can be obtained by combining the data of all liberations, using a modification of the simple Petersen method. In Figure 9, the number of tags returned each week

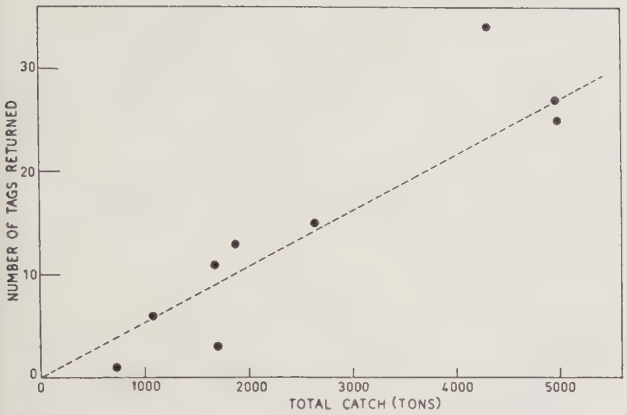


Figure 9. Relation between the number of tags returned and the total weekly catches at Esbjerg for weeks 41 to 49.

have been plotted against the weight of herring landed in that week. These data have been fitted by a simple proportional line, giving 5·4 tags for 1000 tons landed, or correcting for magnet efficiency, $5{\cdot}4/0{\cdot}911 = 5{\cdot}9$ tags/1000 tons. The individual fish may have grown since the time of tagging, so that the 1000 tons of fish in the late autumn represent less than 1000 tons at the time of tagging. However, data from market samples show no significant change in the number of fish per ton, suggesting that the growth in length has been balanced by a decrease in fatness. For the present, therefore, no correction has been made for possible change in weight of individual fish.

The number of herring, effectively tagged, was 4,090. The estimated stock at the time of tagging was, therefore, $4{,}090 \times 1000/5{\cdot}9 = 695{,}000$ tons. In the corresponding period of 1957, fishing was light, and only 5 tags were returned. The herring catches were mixed with large quantities of other species and with small herring. True Bløden herring only amounted to 300 tons. This gives 16·7 tags per 1000 tons, and an estimated population at tagging of $7{,}760/16{\cdot}7 \times 1000 = 465{,}000$ tons.

Spring recaptures

As shown in Appendix 8, substantial numbers of tags from the 1957 and 1958 experiments were recaptured in the spring seasons of 1958 and 1959. Because a proportion of the tagged fish will have left the Bløden area, and because the catches include a large number of small fish newly recruited to the stock, it is not possible to use these data for quantitative estimation of the size of stock. Therefore, these tags (and also a few later recaptures) have not been analysed further for the preparation of this report.

Table 15
Length distribution (%) of total landings in Esbjerg and tagged herring liberated in 1957 and 1958

Length (cm)	Autumn 1957 Total landings	Autumn 1957 Liberation I	Autumn 1958 Total landings	Autumn 1958 All liberations
≥ 27	2·2	–	–	–
26	1·1	–	0·3	–
25	1·8	–	0·6	–
24	1·9	–	1·4	–
23	4·4	–	2·4	–
22	8·1	0·2	4·3	0·1
21	9·3	0·2	7·2	0·2
20	14·6	1·3	12·7	0·4
19	12·8	16·8	15·0	2·0
18	15·0	47·7	21·8	10·0
17	8·1	29·9	17·2	38·4
16	7·3	3·7	11·7	41·2
15	3·7	0·2	3·3	7·3
14	2·8	–	1·2	0·5
13	1·5	–	0·8	–
≤ 12	5·6	–	0·2	–
Number measured ...	3,080	459	4,041	7,855

The effect of fishing

The various estimates of stock size can be summarized as follows:—

1957	Tons
From Esbjerg recaptures within 8 weeks.....	420,000
From later Esbjerg recaptures.....	465,000
1958	
From Esbjerg recaptures within 8 weeks.....	555,000–735,000
From later Esbjerg recaptures.....	695,000
From German recaptures.....	492,000

These estimates are not equally accurate, the early Esbjerg recaptures probably being best. Reasonable mean estimates are, therefore, as follows:—

1957 ..... 420,000 tons
1958 ..... 600,000 tons

The difference between the two years agree well with the changes in catch per unit effort. The Danish catch per hour increased from 1·16 tons in autumn 1957 to 1·75 tons in 1958 (an increase of 51 %). The German catch per trip increased from 19·4 tons to 29·8 tons (an increase of 53 %).

In estimating the effect of fishing on the Bløden stock only the catches from it ought to be taken into account. These will be rather smaller than those given in Tables 4–8. Length frequencies of the total catch landed in Esbjerg during autumn 1957 and 1958 are shown in Table 15, together with length frequencies of the tagged herring. Even allowing for a certain growth taking place during the autumn

season, it is evident that not all of the catch landed could belong to the tagged part of the stock. This applies especially to the bigger fish caught north of the Dogger but also to the 0-group in which the size of the fish (mainly below 15 cm) prevented tagging. Instead of attempting any corrections of catch it was felt safer to include the total catch taken by Denmark and Germany as belonging to the stock tagged, the more so as the overestimate so indicated will counteract any underestimates in the foregoing treatment of the material due to unknown sources of tagging mortality.

Omitting a small quantity of herring landed at Hirtshals as certainly not being part of the Bløden stock (mainly caught in the Skagerak), together with a quantity of some 900 tons taken very far from the Bløden in 1958 (Fladen Ground, etc.) the total catch from the tagged stock is as follows:—

Autumn season	1957	1958
Danish catch	56,021 tons	85,826 tons
German catch	15,000 tons	25,420 tons
Total	71,021 tons	111,246 tons

Therefore, the estimates of the catches taken in the Bløden fishery in 1957 and 1958, expressed as percentages of the stocks present at time of tagging are as follows:—

$$\frac{71{\cdot}0}{420} \times 100 = \underline{16{\cdot}9\ \%}$$

$$\frac{111{\cdot}2}{600} \times 100 = \underline{18{\cdot}5\ \%}$$

Summary

This report is an account of the ICES' Herring Tagging Experiments on the Bløden Ground in 1957 and 1958. A short description of the background for these experiments is given, together with an outline of the history of the project. The execution of the field work is described in more detail, and full particulars of the different liberations are given in Appendices 3 and 4. Only the returns of the internal tags have been considered, and these only for recaptures during the autumn season of the year of tagging. Corrections are made for efficiency of return of tags from the factories, and for the estimated tagging mortality.

Large differences between the pattern of returns from different liberations were found. These were, however, to a large extent eliminated by calculating the local fishing intensity on each liberation from the detailed statistics of fishing effort.

Independent estimates of stock size were obtained from Esbjerg catches within 8 weeks of tagging, and later Esbjerg and German catches. These were in good agreement, and the best estimates of stock size at the time of tagging were 420,000 tons in 1957, and 600,000 tons in 1958.

The catches in the autumn of 1957 were equal to 16·9 % of the stock, and in 1958 to 18·5 % of the stock.

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Appendix 1

Executive Bodies of ICES Herring Tagging Experiment

Participating countries	Delegates at meeting in Copenhagen, February 18th and 19th, 1957	Working Group, appointed by Delegates
Denmark	Dr. Å. Vedel Tåning	Dr. Erik Bertelsen
Germany	Dr. G. Krefft	Dr. G. Krefft
Netherlands	Mr. G. J. Lienesch	Mr. J. J. Zijlstra
Poland	Mr. J. Popiel	Mr. J. Popiel
Sweden	Dr. H. Höglund	Dr. H. Höglund
United Kingdom	Dr. D. H. Cushing	Dr. D. H. Cushing
U.S.S.R.	Not present	Dr. Ju. Ju. Marty
Norway	Mr. Olav Aasen[1])	Mr. Olav Aasen

Convener: Dr. Árni Friðriksson (Secretary General of ICES)

Other appointments by Delegates: –

Naturalist-in-charge: – Chairman of Herring Committee
Financial Administrator: – Secretary General of ICES.

Duties of Naturalist-in-charge: –

1. To charter a purse-seiner with its skipper and crew.
2. To provide gear and equipment.
3. To write a guide on testing the efficiency of magnets in factories to be distributed to the members of the working group and to provide them with unnumbered tags for that purpose.
4. To design a poster giving information on the experiment; this would be translated in each participating country and copies distributed to factories and other centres.
5. To be responsible to ICES for executing the plan.

Duties of Working Group: –

1. To assess the efficiency of magnets in the factories.
2. To collect tags and transmit them to ICES.
3. To ensure that adequate statistics were collected.
4. To advertise the experiment on national information services, including broadcasting.

[1]) Norway did not participate in the scheme by direct financial contribution, but agreed to support the work by giving technical assistance in personnel and equipment. Mr. Aasen was invited, as Chairman of the Herring Committee.

Appendix 2

Scientists participating in work at sea

1957

Pre-tagging survey

		Date
R/S "Jens Væver"		
K. Popp Madsen	Denmark	16/7–23/7
R/S "Platessa"		
A. C. Burd	England	18/7–24/7
G. White	England	18/7–24/7
J. Riley	England	18/7–24/7

Tagging work

R/S "Jens Væver"		
K. Popp Madsen	Denmark	24/7–14/8
M/S "Rygrunn"		
Olav Aasen	Norway	24/7–19/8
E. Bertelsen	Denmark	24/7–31/7
J. Zijlstra	Netherlands	9/8–19/8
H. Knudsen	Denmark	4/8–19/8
J. Popiel	Poland	1/8–14/8
D. H. Cushing	England	24/7– 9/8
G. Bolster	England	9/8–19/8
G. Krefft	Germany	24/7– 9/8
R/S "Sir Lancelot"		
A. C. Burd	England	10/8–26/8
Don Rout	England	10/8–26/8
Gordon White	England	10/8–26/8
Reg. Calver	England	10/8–26/8
R/S "Clupea"		
B. B. Parrish	Scotland	7/8–17/8
G. McPherson	Scotland	7/8–27/8
F. Holliday	Scotland	18/8–27/8
T. Bruce	Scotland	7/8–27/8

1958

Pre-tagging survey

		Date
R/S "Jens Væver"		
K. Popp Madsen	Denmark	24/7– 3/8
R/S "Sir Lancelot"		
D. F. S. Raitt	England	24/7– 3/8
V. Bainbridge	England	24/7– 3/8
J. R. Bridger	England	24/7– 3/8
I. Parmenter	England	24/7– 3/8
R/S "Clupea"		
I. G. Baxter	Scotland	22/7–31/7
R. Watt	Scotland	22/7–31/7
R/S "Willem Beuckelsz"		
K. H. Postuma	Netherlands	24/7– 3/8
M. A. Binsbergen	Netherlands	24/7– 3/8
S. Schaap	Netherlands	24/7– 3/8
R/S "Michael Siedlecki II"		
S. Sadowski	Poland	24/7– 3/8
A. Góra	Poland	24/7– 3/8
J. Kochanowski	Poland	24/7– 3/8

Tagging work

M/S "Rygrunn"		
Olav Aasen	Norway	6/8–29/8
E. Bertelsen	Denmark	6/8–29/8
J. Zijlstra	Netherlands	6/8–29/8
A. Revheim	Norway	6/8–29/8
R/S "Skagerak"		
H. Höglund	Sweden	6/8–29/8
A. Lindquist	Sweden	6/8–29/8
G. Krefft	Germany	6/8–29/8
K. Postuma	Netherlands	6/8–15/8
G. McPherson	Scotland	6/8–29/8
G. Bolster	England	6/8–29/8
J. Popiel	Poland	15/8–29/8
R/S "Sir Lancelot"		
V. Bainbridge	England	6/8–12/8
D. F. S. Raitt	England	6/8–12/8
J. Bridger	England	6/8–12/8
I. Parmenter	England	6/8–12/8

Appendix 3

Details of liberations at Bløden Ground in 1957

Types of tags: (I) Internal, (L) Lea, (D) Danish Lea, (H) Hodgson, (S) Scottish combination with Scottish bridles.
Mode of catch: (P) Purse-seine, (T) Trawl, (N) Drift-net. The totals are sums of figures in brackets.

Lib. No.	Gear	Date	Position N	Position E	Type of tag	Serial numbers	Tags not used (see below)	Total
						R/S "Jens Væver"		175
1	T	28/7	56° 17′	06° 18′	I	C8001–8050 (50)		50
2	P	5/8	56° 04′	05° 57′	L, D	12488–12538 (51), 3251–3325 (74)	1	125
						M/S "Rygrunn'		9,930
I	P	5/8	56° 07′	05° 57′	I	C1–1000 (997), C4001–6000 (1996), 8051–9100 (1048)	9	4,041
II	P	14/8	55° 10′	04° 12′	I	C1001–2000 (1000), 7501–8000 (489), 9101–9600 (500)	11	1,989
III	P	17/8	54° 39′	04° 14′	I	C2001–4000 (2000), 6001–7500 (1500), 9601–10000 (400)		3,900
						R/S "Sir Lancelot'		2,307
1	P	15/8	54° 39′	04° 14′	L, H	5485–5500 (12), 8E221–300 (79), 9E301–500 (200), 10E 901–1000 (100)	5	391
2	T	20/8	54° 41′	04° 00′	I	C12001–12050 (50)		50
3	T	20/8	54° 33′	04° 00′	I	C12051–12150 (100)		100
4	T	20/8	54° 41′	04° 11′	L	12920–12991 (72)		72
5	T	21/8	54° 45′	03° 38′	L	12896–12919 (24)		24
6	T	21/8	54° 45′	03° 58′	I	C12151–12500 (350)		350
7	T	22/8	54° 48′	04° 37′	I	C12501–12551 (51), 12553–12582 (30), 12584, 12599 (2), 12601–12700 (100)		183
8	T	22/8	54° 46′	04° 39′	L	12867–12873 (7), 12885–12892 (8), 12894–12895 (2)		17
9	T	23/8	54° 40′	04° 16′	L	12815–12866 (52), 12874–12884 (11), 12893 (1)		64
10	T	23/8	54° 40′	04° 06′	I	C12552, 12583 (2), 12585–12600 (15), 12701–13450 (750), 13464–13556 (89), 13801–14000 (200)	5	1,056
						R/S "Clupea"		2,107
1	N	8/8	55° 08′	04° 45′	S	AH201–290 (90), 295 300 (6)		96
2	T	8/8	55° 08′	04° 41′	S	AH291–294 (4), 301–600 (300)		304
3	T	8/8	55° 09′	05° 23′	S	AH601–620 (20)		20
4	T	20/8	55° 01′	04° 22′	S	AH621–760 (140)		140
5	T	20/8	55° 44′	04° 04′	S	AH762–766 (5), 768–780 (13)		18
6	T	21/8	54° 44′	03° 52′	I, S	C14045 (1), 14083–14150 (68), AH761, 767 (2), 781–800 (20)		91
7	T	21/8	54° 42′	03° 56′	I	C14001–14044 (44), 14046–14082 (37)		81
8	T	21/8	54° 44′	03° 53′	I	C14151–14200 (50)		50
9	T	21/8	54° 47′	03° 57′	I	C14201–14221 (21)		21
10	T	21/8	54° 44′	03° 51′	I	C14222–14253 (32)		32
11	T	22/8	54° 43′	03° 55′	I, L	C14254–14300 (47), 12992–13074 (83)		130
12	T	22/8	54° 45′	04° 10′	I, S, L	C14301–14450 (150), AH801–1000 (200), AJ001–200 (200), 301–400 (100), C13075–13110 (36)		686
13	T	22/8	54° 43′	04° 02′	I, S	C14451–14593 (142), AJ201–300 (100), AJ401–600 (196)	5	438
							Total...	14,519

Serial numbers not used:- "Jens Væver", Lib. 2(D)3289.
"Sir Lancelot", Lib. 1(L)5486, 5488, 5489, 5490, (H)8E291; Lib. 10 (I)C12599, 13481, 13497, 13554, 13555.
"Rygrunn", Lib. I, C142, 146, 221, 4067, 4943, 5197, 5273, 8051, 8112;
Lib. II., C7551, 7557, 7558, 7561, 7566, 7574, 7578, 7600, 7787, 7791, 7794.
"Clupea", Lib. 13, C14465, AJ424, 525, 563, 590.

Appendix 4

Details of liberations at Bløden Ground in 1958

Types of tags: (I) Internal, (L) Lea, (D) Danish Lea, (B) Bolster. Catching gear: purse-seine throughout. The totals are sums of figures in brackets. 1, 2, 3, 4 = Tagging teams.

Lib. No.	Date	Position N	Position E	Type of tag	Serial numbers	Tag not used (see below)	Total
					M/S "Rygrunn"		6,898
I	9/8	55° 53½′	06° 24′	I	1.C25001–25550 (550), 2.C29001–29500, 29951–30000 (550), 3.C33001–33400 (400)		1,500
II	12/8	54° 43′	05° 20½′	I	1.C25551–26000 (450), 2.C29501–29950, 30001–30007 (457), 3.C33401–34000 (600)		1,507
III	22/8	55° 49½′	05° 32′	I	1.C26051–26300 (250), 2.C30008–30350 (343), 3.C34001 –34500 (500)		1,093
IV	25/8	54° 36′	04° 14′	I	1.C26701–27550 (850), 2.C31001–31800, 31851–32000 (950), 3.C34501–35500 (1000)	2	2,798
					R/S "Skagerak"		4,461
SI	8/8	56° 05½′	05° 36′	L, B	1921–2217, 2241–2324 (381), 1–50, 52, 54, 56, 69, 70, 72, 76, 83–86, 100 (62)		443
SII	9/8	55° 53½′	06° 24′	L	2218–2240, 2561–2759, 2325–2506 (403)		403
SIII	12/8	54° 43′	05° 20½	L, D	2507–2560, 3521–3625, 2761–2880, 3201–3503 (582), 1–100 (100)		682
SIV	13/8	55° 22′	03° 19′	L	3141–3200, 3504–3520, 3626–3689, 3841–3876 (177)		177
SV	22/8	55° 49′	05° 32′	L	3877–4112, 3690–3840, 4161–4300, 4301–4329 (556)		556
SVI	24/8	54° 52′	03° 23′	I, L	4113–4160, 4481–4722, 4330–4480, 4741–5000 (701), 4.C26301–26700 (400), 2.C30401–31000 (599)	1	1,700
SVII	25/8	54° 39′	04° 17′	L	4723–4740, 1601–1742, 961–1300 (500)		500
					R/S "Sir Lancelot"		1,220
LI	8/8	56° 05′	05° 36′	L	1–300 (300)		300
LII	9/8	55° 53½′	06° 24′	L	301–640 (340)		340
LIII	12/8	54° 43′	05° 20½′	L	641–960, 2881–3140 (580)		580
						Total...	12,579

Serial numbers not used:– "Skagerak", Lib. SVI (I), C30639.
"Rygrunn", Lib. IV (I), C31787, C32000.

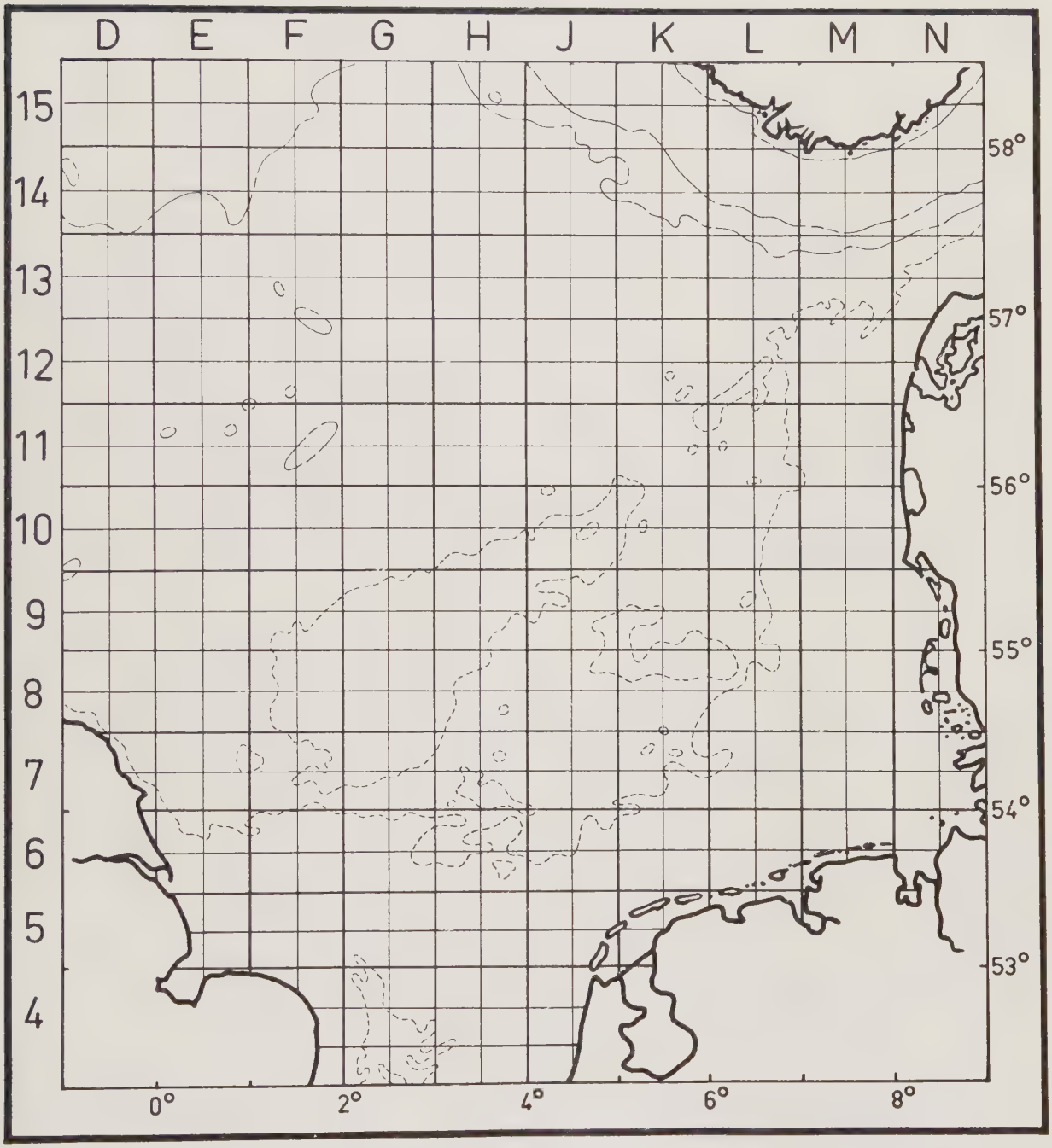


Figure 10. Key to effort data (Appendices 5 and 6).

Appendix 5

Distribution of effort, Esbjerg 1957

Key to effort data in Figure 10 (data for catches taken outside the young herring area are omitted)

	J	K	L	M
12				
		15	162	
11	19	101	422	76
	71	578	52	
10	174	227	169	
	32	53	40	
9	28			

Week 31.

	H	J	K	L
12			42	
			90	34
11			51	243 297 31
		30 75	155	497 240
10	50		264	398 73 144
	50	85 104	109	260 17
9	51	186 565		
8				
7				86

Week 32.

	H	J	K	L	M
12			34		
				45	
11				81	106
				62 77	
10				34 212 104	
			32	82 114	
9		193 157	43		
	43	238 56		13	
8	40 148	42			
	94				

Week 33.

	H	J	K	L	M
11			15	55	417
				62	78	124
10			71	21	9	
			49	52		
9		226	306	63	41	6
	46	97	472	76	42		14		
	68	52	216						
8		15							
		11		9					
7									

Week 34.

	J	K	L	M
12				18	
		177	316		35	142
11		110	403			
		126	511	11		
10		80	464			
	107		138	98			
9	178	160					
		39					
8							

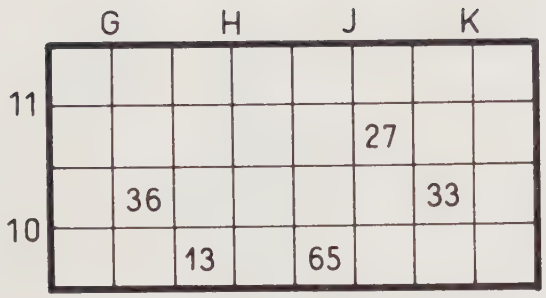
Week 36.

	H	J	K	L	M
12				9	
					100
11			29	41	31	
			201	118			
10		9	450	343			
			361	148			
9							
	148		61				
8							

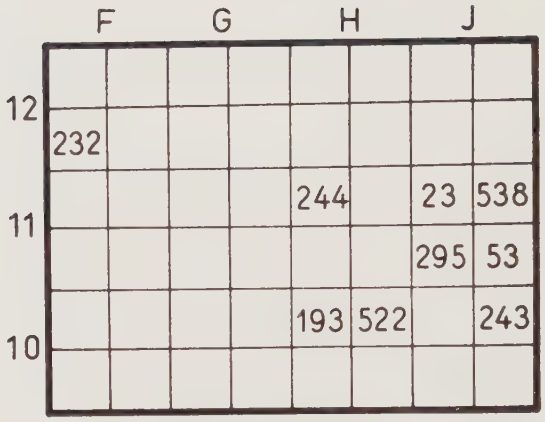
Week 35.

	G	H	J	K	
12				75	63
				99	
11				66	220
				202	205
10	50			133	40

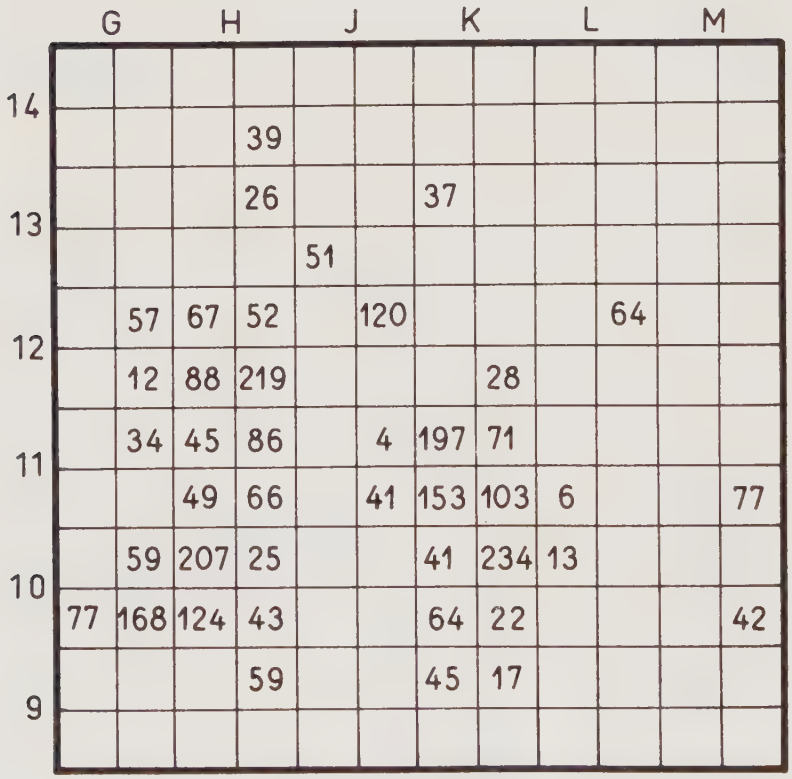
Week 37.



Week 38.



Week 40.



Week 39.

Appendix 6

Distribution of effort 1958

Data for catches taken outside the young herring area are omitted. Key to effort data in Figure 10.

A = Danish effort (Esbjerg) (15 × 15 n. sq. miles) – hours fishing.
B = German effort (Bremerhaven and Cuxhaven) (30 × 30 n. sq. miles) – number of hauls.

Note: – No German Data for Weeks 44–49.

	J	K	L	
12		119	59	
		153	13	57
11	13	183	144	149
		263	158	813
10	33	80	138	509
	71		142	180
9			311	182

Week 33 A.

	F	G	H	J	K
10	2			103	31
9		23	64	116	210
8			3	13	

Week 33 B.

	J	K	L	M
				15
12		101	9	42
		130	264	74	26	
11	42	331	297	131	41	
		149	101	265		
10	87	77	23	145	156		
			31	9		
9						

Week 34 A.

	G	H	J	K
12	5			
11	6	7		
10		73	256	22
9		51	118	
8		289	87	

Week 34 B.

	G	H	J	K	L	M
12				153		36	
				147	36		
11				224	483	509	186		
	45			490	155	153	165		
10			12	83	109	195	47	33	14
	36		79	22	108		12		
9		24	24	10			161		
	35	97			24		47		
8		41							

Week 35 A.

	G	H	J	K	L
13					10
12	4				
11	13				
10		28			
9		31	49		
8		591	38		

Week 35 B.

	G	H	J	K	L	M
12				62					
				90	8	14			
11					50				
					190	95	53		
10				69	25	99			
		116	135	86		464	11		
9	9	41	122		122	32	38		36	
				174	86	279	39	116		
8		53	107	178	215	35		45		
			32	33	72					
7										26	

Week 36 A.

	G	H	J	K
12	5			
11	48	24		
10	22	67		11
9	8	29	37	9
8		220	101	16

Week 36 B.

	F	G	H	J	K	L
12					55 9	
						13
11					25	151
			88		104	106
10		105	62	46	98	130 42
	13	31	92	285 122	67	233
9		41	66	17 57 14 17	23	387 166
				26	224	527 107
8				50	80	

Week 37 A.

	G	H	J	K
11	7	47		
10	40	318	51	
9	57	89	120	12
8	94	16	14	

Week 37 B.

	F	G	H	J	K	L
12					67	28 124
11			62		69	94
		97	21	29	321	640 38
10	27		65	11	293	267 34
		39	319 53	14	223	578
9				75		46 13 25
				100 38		58 213
8				270	46	88
7	42					
	44					

Week 38 A.

	G	H	J
10	97	111	38
9	23	59	350
8		104	68

Week 38 B.

	F	G	H	J	K	L
12						
				142	44	121	26			
			16	7		16		23		
11			156	192	31		65	55		
	89	43	93	31				48		
10			16				254	52		
				42				58		
9				73	47			13	124	
			23	84	103	146				
8										
				57						
7										

Week 39 A.

	H	J
9	9	70
8		23

Week 39 B.

	H	J	K
	41				
11	24	31	62			
				77	133	
10						
					87	
9		167	112			
8		122				

Week 40 A.

	G	H	J
12	3		
11			
10	3	26	8
9		237	221
8		103	11

Week 40 B.

	H	J	K	L
11	75	57	28	99			23
		155	87			43	
10		80	116	52	294		
	209		39		132	45	
9	87			43	212	44	
			149	29	64		
8			19				

Week 41 A.

	H	J
10	13	11
9		53
8	71	34

Week 41 B.

	H	J	K
11				52		33
					161	
10					67	88
9	34					

Week 42 A.

	J
9	50
8	12

Week 42 B.

	H	J	K
					106	
11	25		18	9	92	
					112	20
10					19	

Week 43 A.

	H	J
9	39	8
8	40	

Week 43 B.

Note: – No German Data or Weeks 44–49.

	F	G	H	J	K
11				142	301 42
	61			70	157 71
	193			60 171	268 73
10		330		72 21	222 45
				26 29	43
9				236	
				6	
8					

Week 44 A.

	F	G	H	J	K
	14				
12	24				
	27	14	14		26 99
11		225			24
	13	24			11 44
10		36			182 70
				109	340 150 45
9				21 249	578 61
				33	69
8					

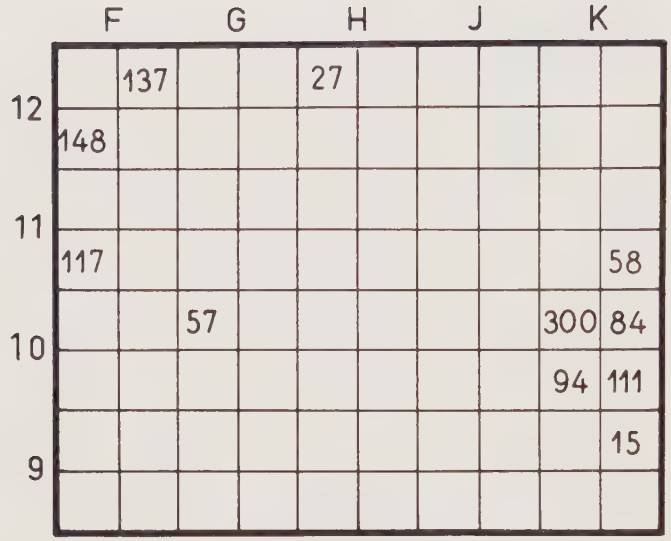
Week 45 A.

	F	G	H	J	K
12		35			
	14	55	6		
11		86			
10					
9					
				34	105

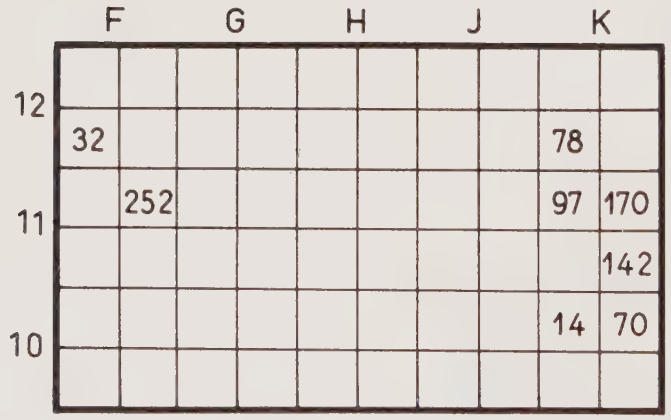
	F	G	H	J	K	L					
12	288										
	99										
11	315				18		109	39			
	49				81	20	40				
10					77	108	45	97			
						62	107				
9					33	21				17	

Week 46 A.

Week 47 A.



Week 48 A.



Week 49 A.

Appendix 7

Total number of tags returned from each liberation up to the end of 1958, separated according to team and order of tagging, e.g., column head 1 are the numbers of tags returned from the first tenth of the fish tagged (e.g., 8 out of 55 for Team 3, Liberation I, 1958)

A) 1957

Liberation I

Order of tagging / Tagging team	1	2	3	4	5	6	7	8	9	10	Total	Total tagged	% returned
1	7	2	4	9	7	6	7	3	4	5	54	997	5·4
2	4	11	10	10	10	7	9	7	8	10	86	1,996	4·3
3	9	14	8	8	10	5	6	5	4	6	75	1,048	7·2
	20	27	22	27	27	18	22	15	16	21	215	4,041	5·3

Liberation II

4	5	8	10	5	11	8	7	9	5	6	74	1,000	7·4
5	5	6	3	1	8	3	7	3	6	3	45	489	9·2
6	1	0	7	5	2	4	6	6	11	1	43	500	8·6
	11	14	20	11	21	15	20	18	22	10	162	1,989	8·1

Liberation III

7	6	6	2	3	1	3	2	6	6	2	37	2,000	1·8
8	6	3	2	6	6	3	0	10	3	2	41	1,500	2·7
9	1	1	0	0	0	1	1	0	0	0	4	400	1·0
	13	10	4	9	7	7	3	16	9	4	82	3,900	2·1

B) 1958

Liberation I

Order of tagging / Tagging team	1	2	3	4	5	6	7	8	9	10	Total	Total tagged	% returned
1	5	11	11	4	2	1	2	4	6	6	52	550	9·5
3	8	11	11	2	8	4	3	3	0	2	52	550	9·5
4	3	1	0	0	2	2	0	3	3	2	16	400	4·0
	16	23	22	6	12	7	5	10	9	10	120	1,500	8·0

Liberation II

1	6	5	5	7	3	6	5	5	5	3	50	450	11·1
3	2	1	4	3	1	0	0	0	2	0	13	457	2·8
4	7	5	2	9	5	2	5	2	0	3	40	600	6·7
	15	11	11	19	9	8	10	7	7	6	103	1,507	6·8

Liberation III

1	2	6	2	4	7	3	3	3	1	2	33	250	13·2
3	4	2	3	4	2	1	2	0	5	5	28	344	8·1
4	4	3	3	3	5	2	2	2	2	4	30	500	6·0
	10	11	8	11	14	6	7	5	8	11	91	1,094	8·3

Liberation S VI

2	2	0	3	3	1	2	0	2	0	2	15	400	3·7
3	4	4	2	0	4	1	3	3	1	2	24	600	4·0
	6	4	5	3	5	3	3	5	1	4	39	1,000	3·9

Liberation IV

1	7	1	2	5	7	5	6	2	1	1	37	850	4·3
3	2	3	2	7	2	3	4	5	0	3	31	950	3·3
4	6	0	1	2	2	3	1	3	2	2	22	1,000	2·2
	15	4	5	14	11	11	11	10	3	6	90	2,800	3·2

Apppendix 8

A) Recaptures from the 1957 experiment up to 31. December 1959

Week	Esbjerg			Other Danish ports			Germany			Other recaptures			Total
	I	II	III	I	II	III	I	II	III	I	II	III	
32	21	–	–	1	–	–	–	–	–	–	–	–	22
33	53	–	–	2	–	–	–	–	1	–	–	–	56
34	48	79	3	12	–	–	–	31	26	–	–	–	199
35	8	12	3	2	–	–	–	6	8	1[1])	–	2[2])	42
36	4	2	8	2	–	1	–	1	4	–	–	–	22
37	7	3	2	1	–	–	–	–	1	–	–	–	14
38	–	–	–	–	–	–	–	–	–	–	–	–	0
39	10	3	–	1	1	–	1	–	–	–	–	–	16
40	–	–	–	–	–	–	–	–	–	–	–	–	0
41	–	–	–	–	1	–	–	–	–	–	–	–	1
42	3	–	–	–	–	–	–	–	–	–	–	–	3
43	–	–	–	–	–	–	–	–	–	–	–	–	0
44	–	–	–	1	–	–	–	–	–	–	–	–	1
45	–	–	–	–	–	–	–	–	–	–	–	–	0
46	–	–	–	–	–	–	–	–	–	–	–	–	0
47	–	–	–	1	–	–	–	–	–	–	–	–	1
48	–	–	–	–	–	–	–	–	–	–	–	–	0
49	–	2	–	–	–	–	–	1	–	–	–	–	3
50	–	2	1	–	–	–	–	–	–	–	–	–	3
51	–	–	–	1	–	–	–	–	2	–	–	–	3
52	–	–	–	–	–	–	–	–	–	–	–	–	0
Total	154	103	17	24	2	1	1	39	42	1	–	2	386
Recaptures in 1958													
	14	12	14	7	2	3	5	–	3	2	–	–	62
Recaptures in 1959													
	–	2	–	1	–	–	6	2	–	–	–	–	11

[1]) From Norway.
[2]) Found in the stomach of whitings.

B) Recaptures from the 1958 experiment up to 31. December 1958

Week	Esbjerg					Thyborøn					Germany					Total
	I	II	III	S VI	IV	I	II	III	S VI	IV	I	II	III	S VI	IV	
33	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13
34	65	–	1	–	–	–	–	–	–	–	–	–	–	–	–	66
35	4	–	6	1	–	1	–	–	–	–	–	–	–	–	2	14
36	8	1	11	3	12	1	–	–	–	–	–	–	–	20	15	71
37	4	8	7	1	4	–	–	1(1)	–	–	–	–	–	–	5	30(1)
38	5	4	14	1	–	–	–	–	–	–	–	–	–	1	2	27
39	6	12	16	1	8	1	–	–	–	–	–	–	–	–	7	51
40	2	–	2	–	1	–	–	1	–	–	–	1	–	–	–	7
41	5	8	8	–	13	1	–	–	–	–	–	–	–	1	–	36
42	–	1	–	–	–	–	–	–	–	–	–	–	–	1	1	3
43	–	4	1	–	1	–	–	–	–	–	–	–	–	–	–	6
44	2	19	5	–	1	–	–	–	–	–	–	–	–	–	–(1)	27(1)
45	1	15	1	1	7	–	–	–	–	–	–	–	–	–	–(1)	25(1)
46	–	7	1	–	3	–	–	–	–	–	–	–	–	–	–	11
47	1	10	3	–	1	–	–	–	–	–	–	–	–	–	–	15
48	–	1	2	–	–	–	–	–	–	–	–	–	–	–	–	3
49	–	7	5	–	1	–	–	–	–	–	–	–	–	–	–	13
50	–	4	2	4	1	–	–	–	–	–	–	–	–	–	–	11
Unknown	–	1	3	3	3	–	–	–	–	–	–	–	–	1	–	11
Total....	116	102	88	15	56	4	–	2(1)*)	–	–	–	1	–	24	32(2)**)	440(3)

*) 1 from Skagen.
**) 2 from Hamburg.

Appendix 9

Distribution of tags and effort for the 1957 and 1958 experiments arranged according to weeks

Number in brackets denote figures reduced in accordance to such efforts during the week of tagging which is supposed to be effective on the tagged stock.

A) 1957
Liberation I

(Effective number of tags 3,000)

Week	Tags	No. of squares	Total effort per square	Tags per unit effort	Tags per 100 hrs per 1,000 tags per square
32	21	2	164		
		4	90		
		12	123		
		Weighted mean	158 (79)	0·266	8·9
33	53	2	70		
		4	35		
		12	52		
		Weighted mean	64	0·828	27·6
34	48	2	70		
		4	49		
		12	18		
		Weighted mean	55	0·873	29·1
35	8	2	36		
		4	18		
		12	19		
		Weighted mean	26	0·308	10·3
36	4	2	–		
		4	9		
		12	108		
		Weighted mean	56	0·071	2·4
37	7	2	–		
		4	–		
		12	41		
		Weighted mean	24	0·292	9·7
38	0	2	–		
		4	–		
		12	–		
		Weighted mean	–		
39	10	2	3		
		4	2		
		12	38		
		Weighted mean	31	0·323	10·8

Liberation II

(Effective number of tags 1,760)

34	79	1	472		
		2	349		
		4	270		
		12	120		
		Weighted mean	432 (423)	0·187	10·6
35	12	1	–		
		2	–		
		4	90		
		12	48		
		Weighted mean	14	0·857	48·7

Liberation II (continued)

Week	Tags	No. of squares	Total effort per square	Tags per unit effort	Tags per 100 hrs per 1,000 tags per square
36	2	1	178		
		2	142		
		4	111		
		12	40		
		Weighted mean	126	0·016	0·9
37	3	1	–		
		2	–		
		4	–		
		12	–		
		Weighted mean	–		
38	0	1	–		
		2	–		
		4	–		
		12	5		
		Weighted mean	3		
39	3	1	–		
		2	–		
		4	–		
		12	8		
		Weighted mean	7	0·429	24·4

Liberation III

(Effective number of tags 3,000)

34	3	1	–		
		2	–		
		4	54		
		12	97		
		Weighted mean	8 (6)	0·500	16·7
35	3	1	–		
		2	–		
		4	15		
		12	17		
		Weighted mean	3	1·000	33·3
36	8	1	–		
		2	–		
		4	10		
		12	28		
		Weighted mean	8	1·000	33·3
37	2	1	–		
		2	–		
		4	–		
		12	–		
		Weighted mean	–		
38	0	1	–		
		2	–		
		4	–		
		12	–		
		Weighted mean	–		
39	0	1	–		
		2	–		
		4	–		
		12	–		
		Weighted mean	–		

B) 1958
Liberation I

(Effective number of tags 930)

Week	Tags	No. of squares	Total effort per square	Tags per unit effort	Tags per 100 hrs per 1,000 tags per square
33	13	1	813		
		2	481		
		4	316		
		12	228		
		Weighted mean	726 (552)	0·024	2·5
34	65	1	265		
		2	198		
		4	198		
		12	172		
		Weighted mean	235	0·277	29·7
35	4	1	165		
		2	176		
		4	253		
		12	182		
		Weighted mean	189	0·021	2·3
36	8	1	–		
		2	27		
		4	62		
		12	82		
		Weighted mean	51	0·157	16·9
37	4	1	42		
		2	21		
		4	69		
		12	80		
		Weighted mean	67	0·060	6·4
38	5	1	34		
		2	36		
		4	244		
		12	213		
		Weighted mean	184	0·027	2·9
39	6	1	–		
		2	–		
		4	26		
		12	41		
		Weighted mean	35	0·171	18·4
40	2	1	–		
		2	–		
		4	–		
		12	11		
		Weighted mean	9	0·222	24·9

Liberation II

(Effective number of tags 680)

33	0	1	–		
		2	–		
		4	–		
		12	38		
		Weighted mean	2 (1)		
34	0	1	–		
		2	–		
		4	–		
		12	3		
		Weighted mean	0		

Liberation II (continued)

Week	Tags	No. of squares	Total effort per square	Tags per unit effort	Tags per 100 hrs per 1,000 tags per square
35	0	1	–		
		2	12		
		4	6		
		12	14		
		Weighted mean	8		
36	1	1	–		
		2	18		
		4	81		
		12	77		
		Weighted mean	53	0·019	2·8
37	8	1	–		
		2	40		
		4	20		
		12	107		
		Weighted mean	64	0·125	18·4
38	4	1	–		
		2	23		
		4	79		
		12	35		
		Weighted mean	39	0·103	15·1
39	12	1	–		
		2	–		
		4	36		
		12	18		
		Weighted mean	18	0·667	98·0
40	0	1	–		
		2	–		
		4	–		
		12	7		
		Weighted mean	6		

Liberation III

(Effective number of tags 500)

34	1	1	101		
		2	199		
		4	220		
		12	130		
		Weighted mean	118 (8)	0·125	25·0
35	6	1	153		
		2	331		
		4	325		
		12	215		
		Weighted mean	212	0·028	5·7
36	11	1	99		
		2	97		
		4	102		
		12	84		
		Weighted mean	96	0·115	22·9
37	7	1	130		
		2	118		
		4	110		
		12	76		
		Weighted mean	104	0·067	13·5

Liberation III (continued)

Week	Tags	No. of squares	Total effort per square	Tags per unit effort	Tags per 100 hrs per 1,000 tags per square
38	14	1	267		
		2	453		
		4	380		
		12	207		
		Weighted mean	289	0·048	9·7
39	16	1	48		
		2	51		
		4	42		
		12	43		
		Weighted mean	44	0·364	72·7
40	2	1	–		
		2	–		
		4	33		
		12	18		
		Weighted mean	18	0·111	22·2
41	8	1	–		
		2	21		
		4	84		
		12	55		
		Weighted mean	54	0·148	29·6

Liberation S VI

(Effective number of tags 470)

35	1	1	35		
		2	66		
		4	39		
		12	24		
		Weighted mean	37 (24)	0·042	8·9
36	3	1	53		
		2	80		
		4	40		
		12	92		
		Weighted mean	61	0·049	10·5
37	1	1	–		
		2	–		
		4	–		
		12	15		
		Weighted mean	3	0·333	70·9
38	1	1	–		
		2	–		
		4	25		
		12	40		
		Weighted mean	20	0·050	10·6
39	1	1	23		
		2	54		
		4	45		
		12	43		
		Weighted mean	43	0·023	4·9
40	0	1	–		
		2	–		
		4	42		
		12	23		
		Weighted mean	22		

Liberation S VI (continued)

Week	Tags	No. of squares	Total effort per square	Tags per unit effort	Tags per 100 hrs per 1,000 tags per square
41	0	1	–		
		2	–		
		4	–		
		12	27		
		Weighted mean	22		

Liberation IV

(Effective number of tags 1,510)

35	0	1	–		
		2	–		
		4	34		
		12	25		
		Weighted mean	3 (2)		
36	12	1	33		
		2	105		
		4	87		
		12	95		
		Weighted mean	59	0·203	13·5
37	4	1	–		
		2	25		
		4	12		
		12	14		
		Weighted mean	13	0·308	20·4
38	0	1	–		
		2	–		
		4	–		
		12	40		
		Weighted mean	12		
39	8	1	–		
		2	51		
		4	47		
		12	41		
		Weighted mean	40	0·200	13·2
40	1	1	–		
		2	–		
		4	30		
		12	33		
		Weighted mean	26	0·038	2·5
41	13	1	–		
		2	10		
		4	5		
		12	20		
		Weighted mean	18	0·722	47·8

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